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GUIDELINES FOR MANAGING THE FLOW OF INFORMATION IN AN AUTOMATED BATTLEFIELD COMMAND AND CONTROL SYSTEM

Cathleen A. Callahan, Robert W. Blum, Gary Witus, and Mark Graulich
Vector Research, Incorporated

HUMAN FACTORS TECHNICAL AREA

U. S. Army
Research Institute for the Behavioral and Social Sciences

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents research directed towards the development and evaluation of guidelines for Standing Operating Procedures (SOP) for managing information flow in automated battlefield command and control systems. This research was performed during the second phase of a project to develop information management concepts and procedures for tactical operations systems. Three stages of SOP guideline development are discussed: (a) identifying critical problems;

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20. Abstract

(b) developing candidate management procedures to address the critical problems; and (c) evaluating the efficacy and side effects of the candidate procedures.

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GUIDELINES FOR MANAGING THE FLOW OF INFORMATION IN AN AUTOMATED BATTLEFIELD COMMAND AND CONTROL SYSTEM

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Information Systems
Management

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FOREWORD

The Human Factors Technical Area of the Army Research Institute is concerned with aiding users/operators to cope with the ever-increasing complexity of the man-machine systems being designed to acquire, transmit, process, disseminate, and utilize tactical information on the battlefield. The research is focused on the interface problems and interactions within command and control centers and is concerned with such areas as tactical symbology, user oriented systems, information management, staff operations and procedures, systems integration and utilization as well as issues of system development.

An area of special concern is the development of procedures for effective system control and utilization. The inevitable need for engineering tradeoffs during system design often results in systems which are unmanageable or which at best achieve only a small portion of their potential. Explicit attention to the procedures to be followed by the user can compensate for some of these problems, particularly if accomplished early enough in the development cycle. The present publication is one of several from a project with an initial focus on the Tactical Operations Systems (TOS) and an initial goal of the development of procedures for managing the flow of information in TOS. The present report reflects the redirection of the TOS development program, and provides guidelines for managing information flow in automated battlefield systems in general. These guidelines and accompanying analyses establish the basis for definition and implementation of management procedures in a variety of information processing systems.

Research in the area of information management is conducted as an in-house effort augmented through contracts with organizations selected for their unique capabilities and facilities for research in this area. The present study was conducted by personnel from Vector Research Inc. under contract DAHC19-78-C-0027 and directed by Dr. Stanley M. Halpin and Mr. Robert S. Andrews. This effort is responsive to requirements of Army Project 2Q163739A793 and to the Combined Arms Combat Development Activity, Fort Leavenworth, Kans., and Communications R&D Command (CORADOCOM), Fort Monmouth, N.J. Special requirements are contained in Human Resources Need 80-305, Information Management Within the Tactical Operations System.

Joseph Zeidner

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Technical Director

GUIDELINES FOR MANAGING THE FLOW OF INFORMATION IN AN AUTOMATED BATTLEFIELD COMMAND AND CONTROL SYSTEM

BRIEF

Requirement:

This part of a project to develop information management concepts and procedures for automated battlefield command and control systems (ABCCS) was intended to describe how design parameters of contemporary ABCCS can affect other system management tasks, and to provide (a) procedures for managing ABCCS and (b) methods and monitoring statistics needed to manage field operations.

Procedure:

A congestion analysis of TOS (*a specific command and control system*) and its supporting communications parameters indicated specific upper limits on the utilization of any component (80% of full capacity). The analysis identified the most severe specific management and communications problems to be expected in field operations. With data from the TOS example, management guidelines were developed for controlling the demand on components and preventing or remedying an overload.

Results:

Management procedures effective in controlling excessive demands on computer, communications, and user are (1) control of the number of incoming message retrieval requests, (2) use of operating levels, (3) purging of useless data, (4) removal of users from distribution lists, and (5) hierarchical review.

The system controller can detect a potential overload and avoid a system crash by considering the interaction of (1) the responsiveness required of the system, (2) the methods of measuring the utilization responsiveness threshold, and (3) the procedures available to correct the problem.

Utilization:

These guidelines and accompanying analyses establish the basis for defining and implementing management procedures in a variety of information processing systems.

PREFACE

This document is one of eight reports which describe the work performed by Vector Research, Incorporated (VRI) and its subcontractor, Perceptronics, Incorporated, for the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) under the second phase of contract number DAHC19-78-C-0027. The work described was performed over 12 months of an anticipated 36-month three-phased project. The overall objective of the project has been to produce procedural guidelines to be used by divisions in the field in developing standard operating procedures for information management in the Tactical Operations System (TOS). As a consequence of the redirection of the TOS development effort in November 1979, the objective of this work was reinterpreted to include automated battlefield command control systems (ABCCS) in general, using TOS for an explicit example of the design, human factors, and management control considerations which must be addressed.

The VRI study team for phase II was comprised of Dr. Robert W. Blum (Project Leader), Ms. Cathleen A. Callahan, Dr. W. Peter Cherry, Mr. Mark G. Graulich, Mr. Donald Kleist, Mr. Mark Meerschaert, Mr. Gregory Touma, and Mr. Gary Witus. The Perceptronics team for phase II consisted of Dr. Michael G. Samet and Dr. Ralph E. Geiselman.

The authors wish to acknowledge the helpful contributions of Dr. Stanley M. Halpin and Mr. Robert Andrews, who were charged with monitoring the study for ARI; and LTC L. Walker, MAJ A. Edmonds, and Mr. M. Carrio, who performed a similar function for that portion of the study effort which was jointly sponsored with ARI by the U.S. Army Communications Research and Development Command (CORADCOM).

The eight reports are as follows:

Blum et al., Information Management for an Automated Battlefield Command and Control System: Executive Summary, ARI Research Report 1249 -- presents an overview of the project and the other seven reports.

Callahan et al., Guidelines for Managing the Flow of Information in an Automated Battlefield Command and Control System, ARI Research Report 1248 -- describes considerations in and procedures for the management of contemporary ABCC systems.

Geiselman and Samet, Guideline Development for Summarization of Tactical Data, ARI Technical Report 458 -- an analysis of procedures for the extraction, summarization, and presentation of critical information.

Witus et al., Analysis of Information Flow in the Tactical Operations System (TOS), ARI Research Note 80-12 -- describes the purpose, approach, and results of a TOS analysis which focused on TOS when integrated with a planned communications support system.

Witus et al., Description of the Tactical Operations System Information Flow Model, ARI Research Note 80-13 -- describes the representation of TOS used to develop the analysis package and the mathematics of the model.

Witus et al., User's Manual for the Tactical Operations System Analysis Package, ARI Research Note 80-14 -- explains the use and operation of the analysis package.

Witus et al., Programmer's Manual for the Tactical Operations System Analysis Package, ARI Research Note 80-15 -- describes the programming details of the package to facilitate modifications or transfer between host systems.

Cherry, WP, All Source Analysis System: Design Issues, ARI Working Paper HF80-XX -- a discussion of design issues associated with the emerging ASAS concept.

GUIDELINES FOR MANAGING THE FLOW OF INFORMATION IN AN AUTOMATED BATTLEFIELD COMMAND AND CONTROL SYSTEM

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GUIDELINES FOR MANAGING THE FLOW OF INFORMATION IN AN AUTOMATED BATTLEFIELD COMMAND AND CONTROL SYSTEM

1.0 OVERVIEW

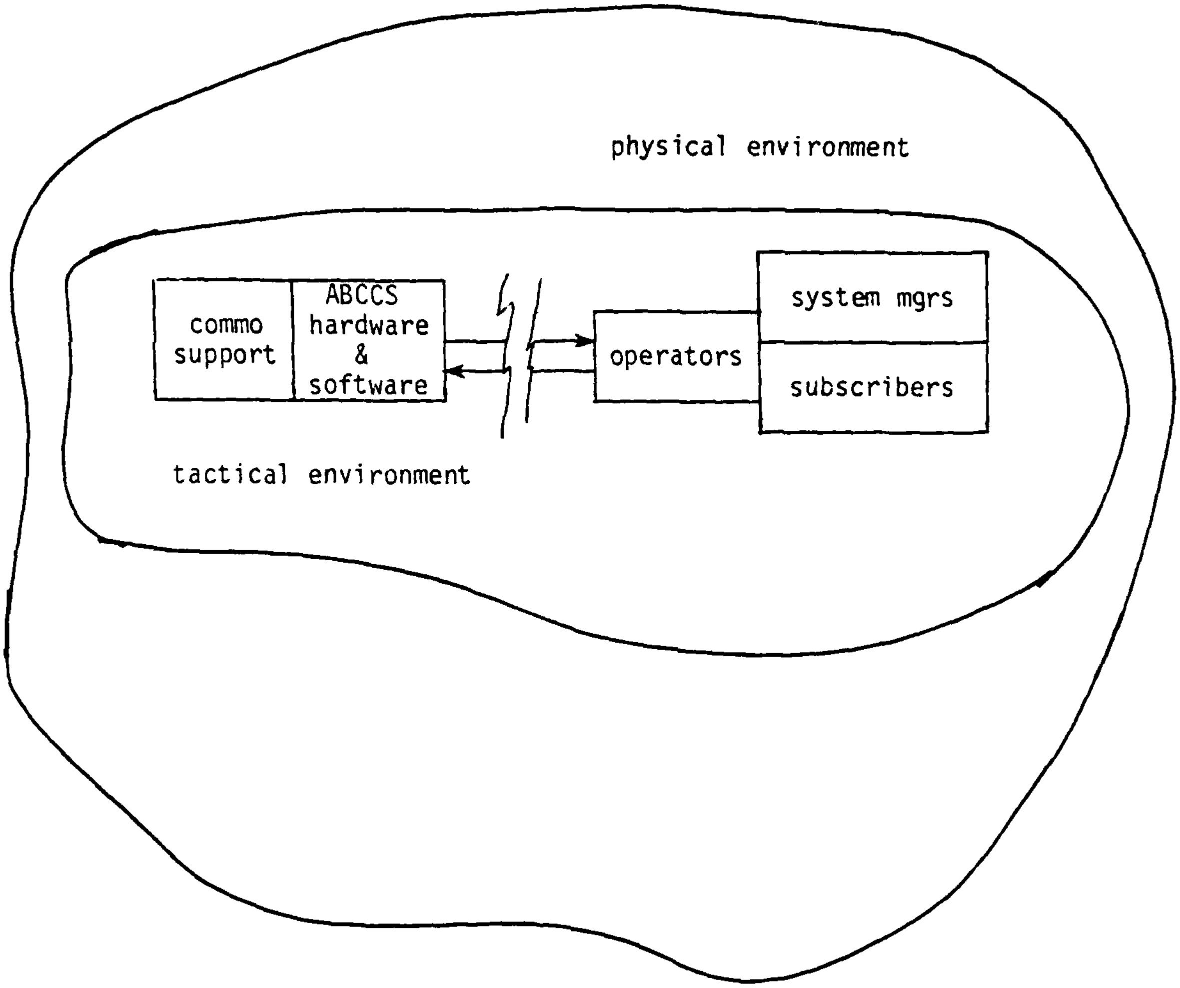
This report of the project described in the preface is concerned with: (1) revision and expansion of the provisional SOP guidelines and (2) evaluation methodology and criteria. The methodology for evaluating the guidelines was planned originally (1978) to use hardware and software prototypes in a field test environment. When it became apparent that such prototypes would not be available as expected, a generic automated battlefield command and control system (ABCCS) was described in the form of a mathematical model. In order to use that model to study the Tactical Operations System (TOS), its parameters were quantified from the developing system design and assumed to be representative of TOS as it might have been fielded. The evaluation criteria were developed jointly with the TOS communications network model. As a consequence of that research, the revised and expanded SOP guidelines were directed toward managing and controlling the demands imposed on each of the system components so as to avoid overloading any of them or, if one does become overburdened, to reduce the demand to a tolerable operation condition. The principal function of this overview chapter is to summarize the reasoning which led to the guidelines assuming that orientation.

Automated battlefield command and control systems (ABCCS) of various types are being developed by the army for fielding in the 1980s. Other than TOS, whose development was arrested by congressional action in November 1979, some prominent examples of contemporary ABCCS in varying stages of development are TACFIRE I, ASAS, and ECS^2. When imagining such a system, one might tend to focus solely on its hardware and software, but such a view would be unfortunately myopic. The degree to which the operational potential of any ABCC system is achieved depends to a large extent on the degree to which a number of extended system elements are recognized (by both the development and requirements communities) to affect the system's operation and are treated accordingly. These system elements are:

- users (operators, subscribers, and managers/controllers);
- hardware and software;
- supporting communications; and
- tactical and physical environments.

Exhibit 1-1 illustrates these elements of an extended ABCC system in which the communications, hardware and software, and users are jointly embedded in the tactical environment which, in turn, is embedded in the ambient physical environment.

EXHIBIT 1-1: ELEMENTS OF AN EXTENDED ABCC SYSTEM



ABCC systems are characteristically automated, but not automatic. They interact with humans (operators, system subscribers, and system managers or controllers). Through those interactions, ABCCS pass information to these system users and receive information and instructions from them. An interface exists between the system and the system users. Part of that interface may be deliberately designed during the development process, but some part of it can usually, if not always, be expected to be an implicit consequence of other design considerations and the operational environments.

An inevitable fact of life in any information system is that any of the system components are subject to overload and subsequent impaired performance. The overloads may occur for a number of reasons:

- a user/subscriber is overburdening some portion of the system;
- the tactical environment is degrading the system's capability to perform;
- the physical environment is degrading the system's capability to perform; or
- the system is overburdening some user-operator or user-subscriber.

Each of the above situations requires some form of management control and is occasioned by the capacity of some component of the extended system being less than sufficient to accommodate the demand being placed upon it. Since capacity is a system characteristic resulting from its design and temporarily fixed by its operating environment, it cannot be changed at will. Therefore, the burden on the component (an ABCC hardware component, supporting communications component, or user--either operator or subscriber) being overloaded must be altered to bring demand into line with capacity so as to reduce the congestion at the problem component.

Setting aside for the moment the manager's problem of identifying the congested component needing relief and assuming that the identification has been made, the manager must be judicious in selecting the means to relieve the overload; any control procedure will inevitably alter the quantity of information being handled by the congested component and, therefore, the quantity of information available to the ABCCS users. The means for reducing an overload should be carefully selected to ensure that the quality of information which results is not unnecessarily degraded as the quantity of information is reduced. In fact, various techniques have been developed in the field of information science which can actually increase the quality of a corpus of information by reducing its irrelevancies and other inherent obstacles to its easy assimilation by a user.

For managing any type of ABCC system, alternative procedures can be devised for controlling the quantity of information handled by a given system component. Each alternative will have more or less effect in reducing information flow because each alternative is fundamentally oriented toward altering the flow of information due to a unique cause. Some examples of such causal agents in TOS would be excessive message input or output traffic at a terminal (analogous to a Wall Street ticker tape running well behind the

floor transactions), numerous standing requests for information newly entering the data base, very busy communications links, and undesirably rapid growth in the size of the data base. Even though a particular procedure might have the greatest capability for directly reducing the quantity flow of information through an overloaded component, good professional judgment might suggest that a less powerful indirect procedure or combination of procedures should be employed instead. Human judgment in situ is essential in choosing which alternatives are most desirable in a given situation for maintaining the quality of both the information flow and the data base, therein making the tradeoffs between quantity and quality which are inherent to the management process.[1] Because of the importance of quality to the overall worth of information, each of the procedures for controlling information quantity in an ABCCS described in this report is accompanied by a brief discussion of the general quality considerations which may be attendant to a decision to employ that procedure.

Setting aside considerations on information quality, common sense tells us that selecting a management control procedure for altering the flow of information through an overburdened system component requires that the responsible manager be able to discern that a problem exists or, preferably, is about to exist, where it exists, and why. If the existence of an overload problem is not discernable until it becomes catastrophic or the manager remains ignorant as to the location of the problem, it is likely that the system cannot be controlled by management procedures. If the manager or controller is kept unaware of the sources of the various demands which have accumulated to the extent that they are causing a component to be unduly stressed, he will be unable to choose, except by chance, the control procedure most appropriate for dealing with that situation. Therefore, the status of the system, both as a whole and for each of its components, must be monitored continually and provided to the responsible manager. Proper provisions for monitoring the status of ABCC system components, to include the network links of the supporting communications system, must be included in the ABCCS hardware and software designs. That monitoring capability is the interface between the ABCCS proper and the system manager. If it is not an explicit part of the design, but is left to field expedients, the most clever of those ad hoc methods may still be inadequate for tracking the status of the system. The extent to which the management interface should be incorporated into the system design is governed by two major considerations, the first a function of the design of the system upstream from the interface and the second a function of the downstream problem:

- the magnitude of the system control tasks which are left for the manager to perform; and

- the availability of status information in the detail necessary for effective performance of those system control tasks.

---

[1]The disciplined field of decision theory contains structured methods which can be applied to the problem of guiding a manager in making tradeoffs between quantity and quality. Situations in which such management decisions are required are characteristically changing, and dealing with changing situations satisfactorily often entails making continual changes in the value systems on which decisions are made for managing in those situations.

It seems clear that these two considerations are likely to change together; if the magnitude of the management task becomes large, so will the amount of status information to be monitored, and vice-versa.

The purpose of the work being reported here is threefold. It is to describe:

- how hardware and software design parameters of the kinds of ABCC systems and supporting communications under contemporary consideration by the Army can affect the magnitude of the remaining system management tasks;

- procedures for managing the system burden; and

- typical monitoring statistics necessary to system management in field operations.

In helping to fulfill the purpose described above, it is helpful to use an example which has relevance to an actual ABCCS. TOS, as it might have been described in November 1979, is used here as the example of a contemporary ABCC system. Extensions from that particular example are assumed (for example, a freeze in a component design in such a manner that a given problem becomes more or less prominent) when useful in explaining particular management procedures and the circumstances for their possible use.

This document is organized into three chapters in addition to this overview. Chapter 2.0 summarizes an analysis of the example TOS and its supporting communications design parameters. That analysis revealed that the upper limit on the utilization of any component is characteristically 80 percent of its full capability, identifying that 80 percent utilization level as the capacity of the component if it is to operate within acceptable levels of responsiveness. The analysis determines that the most severe management problem that could be expected in field operations is overburden of FM communications nets, a problem which is serious even in the presence of fairly modest bit error rates and exacerbated when retransmission stations are used. If the FM communications problem were to be relieved, the next two component overburden problems in order of severity could be expected on the multichannel communications links and at the message and data disk controllers of the main frame computer. The software design was not sufficiently mature by November 1979 to determine the memory space that would be available for maintaining data files and the space which would be dedicated to buffering the front-end processor (FEP) or the remote terminals. In consequence, the analysis did not extend to these areas, even though management procedures can be postulated for controlling the burdens at those components.

Chapter 3.0 describes the management control procedures which have been identified and investigated for controlling the burden of demand on various system components. It discusses the possible causes for employing each of those procedures, individually or in sets, and the expected marginal effects on the system. As indicated earlier, it also discusses some of the implications which considerations of information quality might have on selection of

a given control procedure. Wherever applicable to the procedure being discussed, the TOS example developed in chapter 2.0 is used as a case in point. Otherwise, plausible extensions to that example are assumed as needed to help explain a management procedure in the context of a specific causal agent.

Chapter 4.0 discusses the need for the system manager/controller to be able to monitor continually the status of the system as a whole and of each of its components in order to identify when and where a problem is developing or already exists which might need management attention. The chapter also summarizes the example monitor statistics described in chapter 3.0 which could be expected to be helpful in diagnosing the status of the system and in determining an appropriate management action to resolve an operational problem. The reasons why those statistics must be made available by design at the management interface of the system with its users and must not be left to field expedient methods have been covered in this overview discussion, but also become evident in the discussion of the example monitoring statistics.

2.0 INFORMATION FLOW CONGESTION

Initial analysis of TOS, the example ABCCS, identified the likely areas of congestion in the information flow, and provided the basis for the design of management procedures to detect and reduce congestion in TOS. The analysis identified traffic flow in communications systems as the major contributor to congestion. The FM nets were identified as the primary critical components. The Division multichannel net and the disk controllers in TOS proper were identified as secondary critical components. These components will operate effectively provided that their utilizations do not exceed 80 percent. The analysis results supporting these conclusions are summarized in the remainder of this chapter.[2] The software design was not sufficiently mature by November 1979 to determine the memory space required or available for data files and front-end processor (FEP) buffers. In consequence, the analysis did not extend to these areas, even though management procedures can be postulated for controlling the burdens at those components.

2.1 ANALYSIS PURPOSE AND APPROACH

The purpose of the analysis was to determine the operational requirements of TOS and to evaluate the capability of the proposed system to meet the requirements. The analysis approach was organized into a series of objectives. Three objectives addressed traffic flow congestion in the example TOS; the others addressed design issues. The results summarized in this chapter relate to the first three objectives and pertain to the example TOS:

(1) identify the critical system components; i.e., the components most likely to become choke points and cause degradation of the system;

(2) establish operating guidelines which would prevent choking at the critical components; and

(3) evaluate the impacts of the field conditions on the performance of the primary critical components.

The primary tool used in the analysis was a mathematical model of the steady state network performance based on a representation of TOS as a queueing network. The network components are the FM nets, multichannel net, tactical computer terminals (TCTs), tactical computer system (TCSs), and the disk controllers, front-end processor and data base processor in the division computing center (DCC). The model used a set of inputs describing: (1) network configuration; (2) the engineering characteristics; (3) the operational procedures; (4) the user demand; and (5) the electromagnetic environment. The model computed three outputs for each component: (1) utilization--the fraction of time the component would be busy; (2) expected queue length--the average number of messages waiting for service; and (3) expected delay for

---

[2] The analysis is documented in four other volumes of the report which are identified as ARI Research Notes 80-12 through 80-15. Full titles are listed in the preface.

a message--service time plus waiting time. The level of detail of the model corresponded to the detail in the A-level and draft B-level system specifications.[3] Where alternative procedures were under considerations, alternative sub-models were prepared.

2.2 CRITICAL COMPONENTS

A five stage procedure was used to identify the critical components:

(1) define a baseline case;

(2) examine the sources of delay in the baseline case;

(3) examine component utilization in the baseline case;

(4) examine the ability of the system to meet the user's delay requirements in the baseline case; and

(5) consider impacts of further degradation from adverse field conditions.

The baseline case consisted of the network configuration as shown in exhibit 2-1, the user's projected peak hour traffic rates, no voice competition on the nets, no FM retransmission stations, and a realistic range of error rates for transmission between two network nodes (0 to 10 bits in error per thousand bits transmitted).

The chart in exhibit 2-2 shows the breakdown of the expected total delay in transmitting and processing a message sent from a battalion in contact to the Division Computing Center. The FM net accounts for almost 98 percent of the delay at zero erro rate, and the percentage is larger at higher error rates. The delay at the FM net consists of the time a message spends waiting to get on the net, and the transmission time. The transmission time includes overhead to establish the link and time to transmit the body of the message. As the error rate increases, the probability that a message must be retransmitted due to errors increases, and hence the transmission time increases. As the transmission time increases, the fraction of the time the net is busy increases, and consequently the waiting time increases.

A second approach to identifying the critical components is to examine the fraction of time that the various components are engaged. A chart showing the maximum utilization of various types of network components is presented in exhibit 2-3. No components other than the FM nets are busy more than 10 percent of the time, while at a five bits per thousand error rate the utilization of the Cavalry Squadron FM net exceeds 80 percent.

---

[3] System Specifications for the Division Tactical Operations System (DTOS), CO-SS-3000-TO, April 1979, and Computer Program Item Specification Network Communications Processing for Division Tactical Operations System (DTOS), CR-CS-0002-B12, 25 May 1979.

EXHIBIT 2-1: NETWORK CONFIGURATION

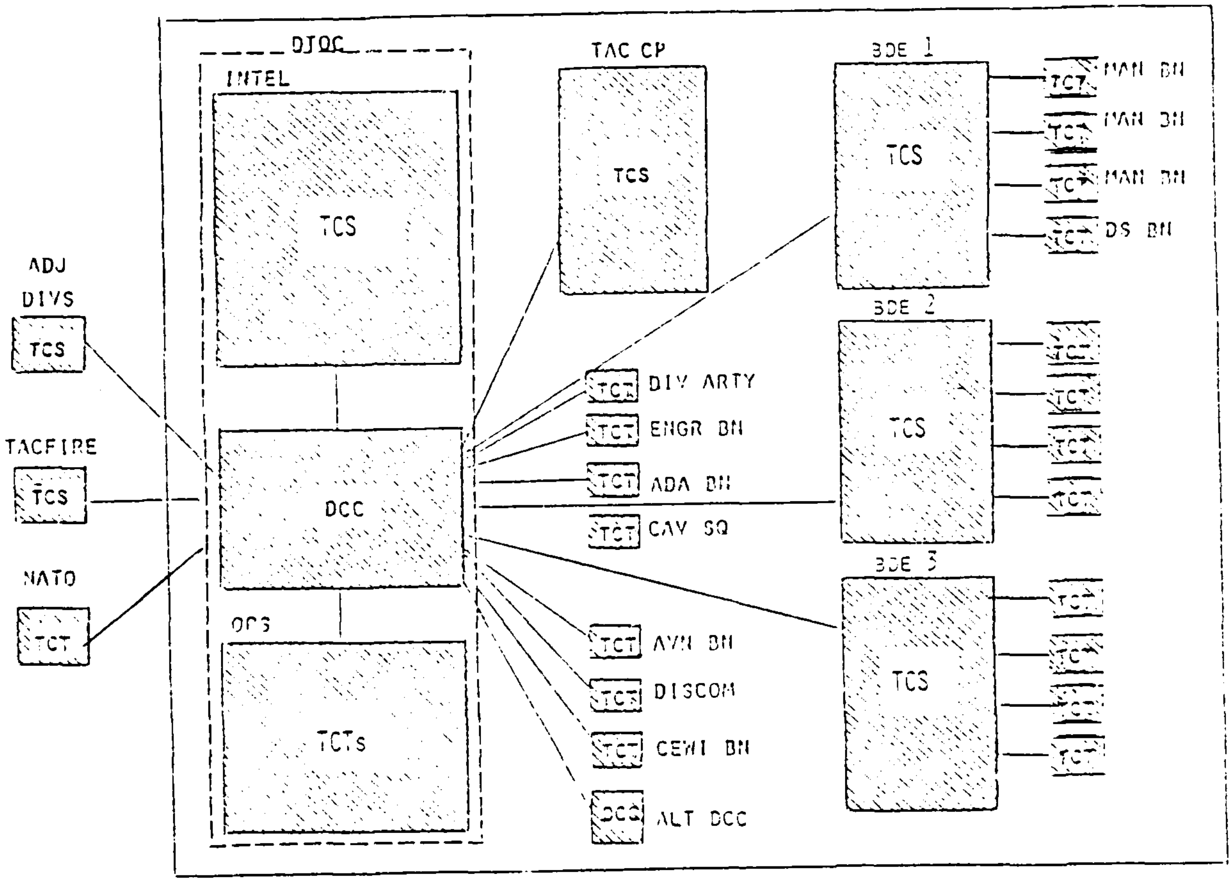


EXHIBIT 2-2: BREAKDOWN OF EXPECTED DELAY

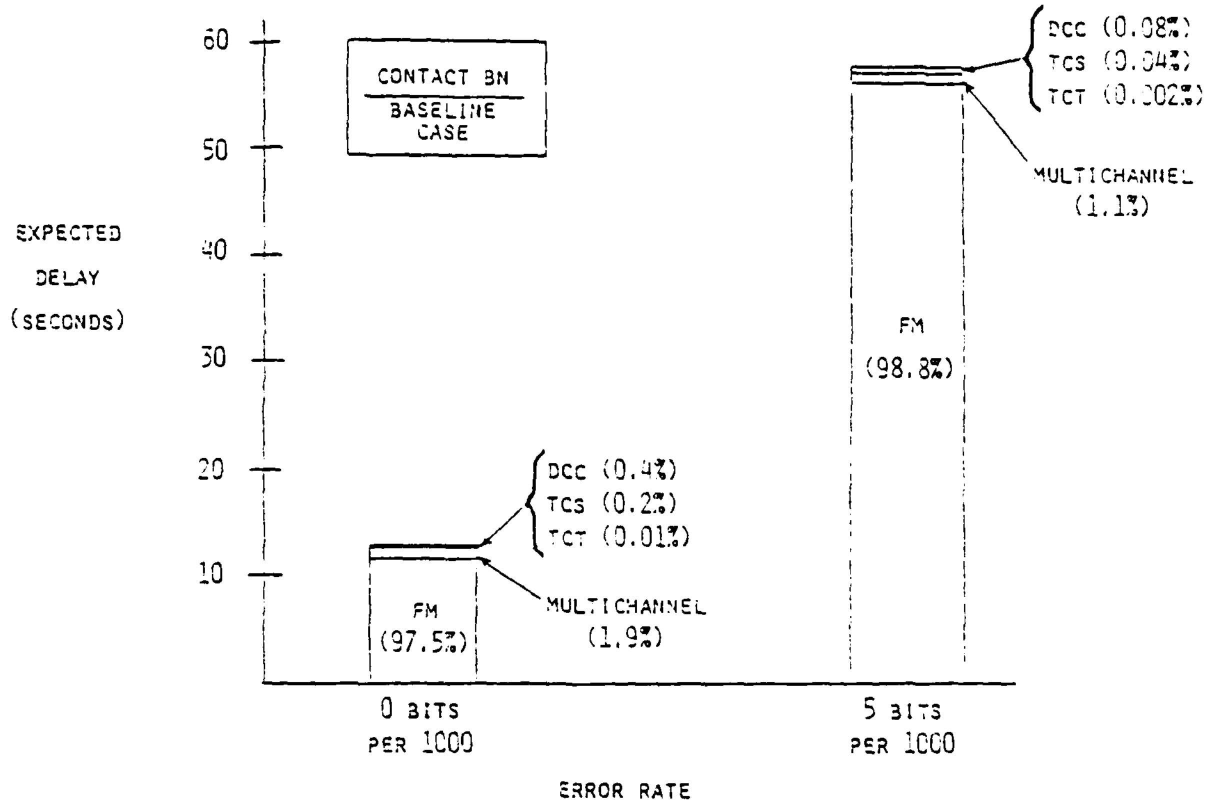
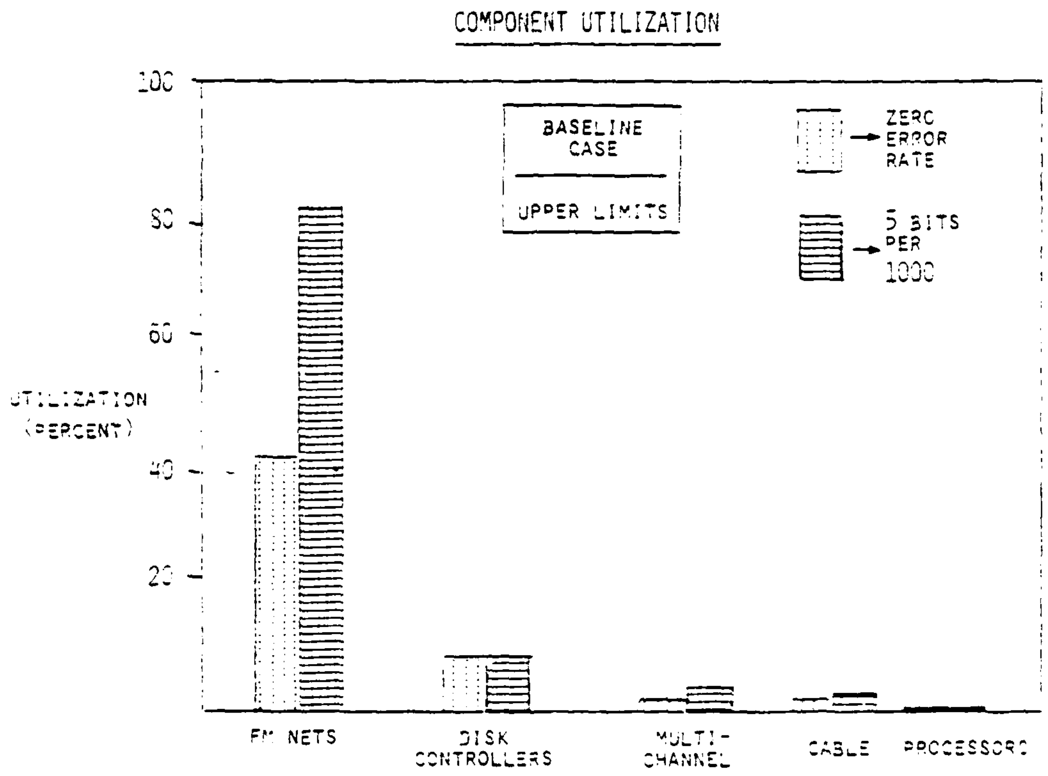


EXHIBIT 2-3: COMPONENT UTILIZATIONS



The user's requirements statement referenced in the system specifications provided a range of maximum tolerable delays taking into account variations in message length, network configuration, and traffic intensity. As shown in exhibit 2-4, the average delays on some of the FM nets exceed the upper limit of the tolerable range at lower error rates than would cause the average multichannel delay to exceed the even lower limits.

Based on the foregoing analysis, the FM nets were identified as the primary critical components. Furthermore, the performance of the FM nets can be severely degraded by adverse field conditions. For example, the FM nets are to be shared with voice transmission and hence are not 100 percent available for data transmission. In addition, retransmission stations are used to extend the range of some FM nets. The use of retransmission stations requires a longer overhead time to establish a link, and the multiple transmissions produce a compounded error rate.

The multichannel net is, like the FM nets, susceptible to transmission errors. Due to the higher transmission rate (32 kbps for multichannel vs. 1.2 kbps for FM) and shorter link-up overhead (0.1 seconds for multichannel vs. 1.5 seconds for FM without retransmission stations), the multichannel net is able to operate effectively at error rates much higher than could be tolerated on an FM channel. The multichannel net does not become seriously congested until error rates in excess of 15 bits per thousand are reached.

The congestion level at the disk controllers depends in part upon the system software. The software design was not sufficiently mature by November 1979 to permit definitive analysis of the congestion at the disk controllers. The disk controllers are slow devices and unless the software was designed to minimize the demand on the controllers, the utilizations could easily be as high as the 8 percent shown in exhibit 2-3. This potential for overload motivated the identification of the disk controllers, along with the multichannel nets, as secondary critical components.

2.3 OPERATING GUIDELINES

The provisional TOS standing operating procedures[4] provide for system control via control of the rate of user access to the system. By this means the System Controller can control the traffic rate on any net. The FM nets exhibit a characteristic response curve relating the expected delay to the traffic rate on the net. An example of this response curve for the CAV SQN FM net is shown in exhibit 2-5. The response curves for the other FM nets differ slightly as a consequence of the different mix of messages travelling over each net. The curves do, however, have some important characteristics in common. Expected delay responds slowly to changes in the traffic rate when the net is operated below 80 percent utilization, the curves exhibit a knee beyond 80 percent utilization. Traffic rate is, therefore, a nearly linear control for expected delay as long as the net is operated below 80 percent utilization. Similar response curves define the relationship between

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[4]See ARI Working Paper HF79-1.

EXHIBIT 2-4: EFFECT OF TRANSMISSION ERROR RATE ON EXPECTED DELAYS

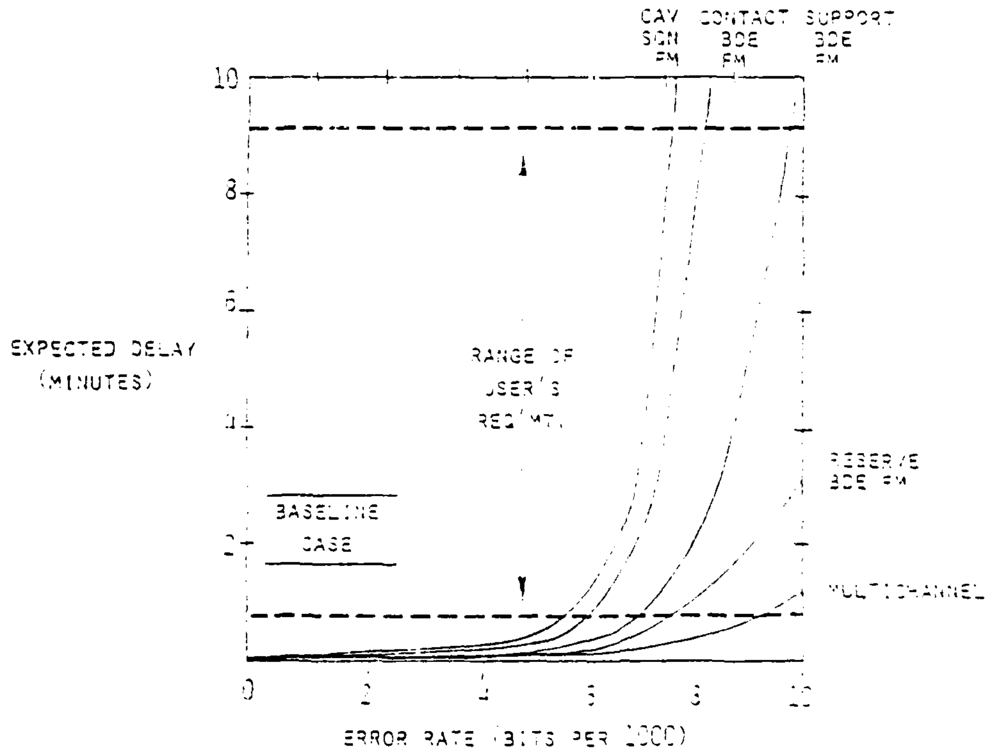
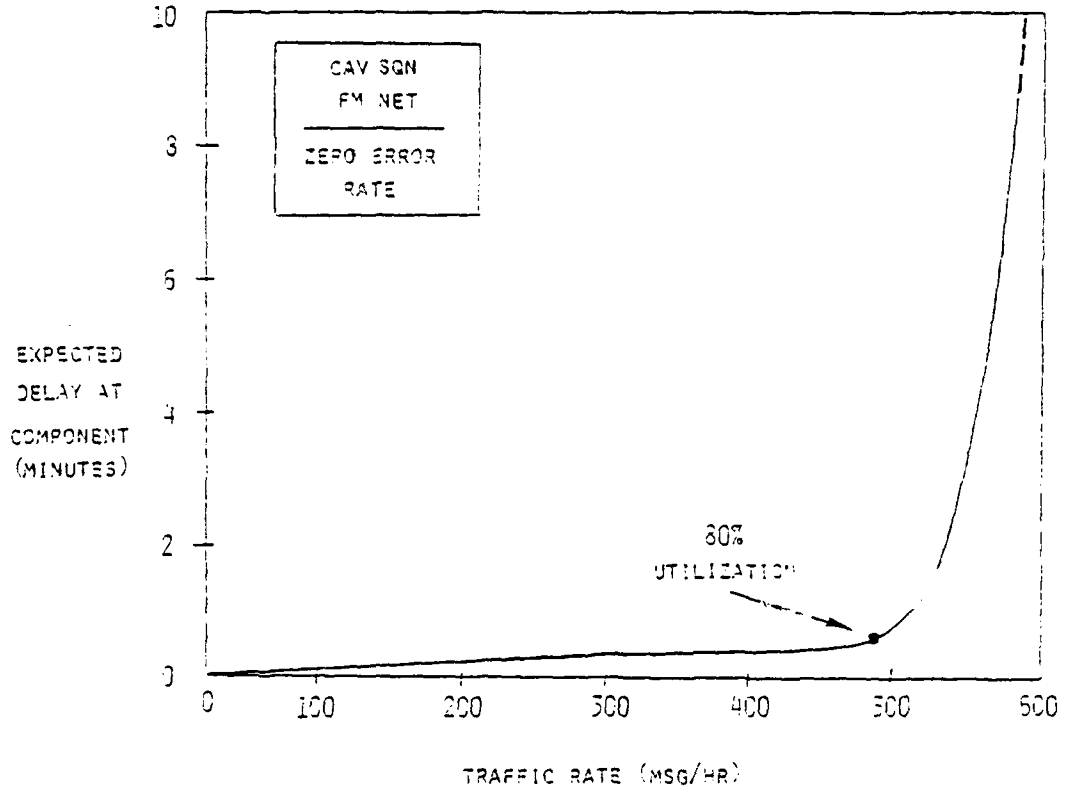


EXHIBIT 2-5: SIGNIFICANCE OF 80 PERCENT UTILIZATION



expected queue length and traffic rate. The operational capacity of the net may be defined as the traffic rate which produces a utilizaton of 80 percent. A sharp guideline for avoiding performance degradation due to congestion on a communication net is to keep the demand within the operation capacity.

2.4 FIELD CONDITIONS

Various field conditions affect the performance of the FM nets. Foremost among these are the presence of transmission errors and the use of retransmission stations. Exhibit 2-6 shows the effects of the transmission bit error rate on the capacity of the CAV SQN FM net without retransmission stations. The net can support the projected peak hour load up to an error rate of approximately 5 bits per thousand.

It is likely that a cavalry squadron on a covering force or flank security operation will use several retransmission stations to communicate with its division headquarters. Retransmission stations increase the link-up overhead time and produce a compounded error rate. Equipment tests and theoretical computations indicate that at the error rates under consideration, "n-1" retransmissions produce a cumulative error rate of approximately "n" times the error rate for a single transmission. Exhibit 2-7 presents graphs of the CAV SQN FM net capacity with zero and three retransmission stations. The x-axis is the error rate for a single transmission. The retransmission stations severely degrade the net's capacity: with the retransmission stations the net cannot support the required traffic at error rates above one bit per thousand. Exhibit 2-8 presents graphs of the CAV SQN FM net capacity when the net is occupied by voice 0 and 25 percent of the time, and demonstrates the reduction in operational capacity as a result of voice competition.

2.5 SUMMARY

It is clear : 'om this analysis of TOS that the information flow must be carefully managed if such systems are to be kept operationally viable in the field. Most of the attention of the System Controller will be directed to controlling the traffic flow over the various links of the supporting communications system, and attempting to ensure that the quantity and quality of information which flows to the various users as a result of that control process continues to meet the tactical information needs of the division. The following chapter provides a set of procedural recommendations which, if implemented, will supply the necessary tools to allow such traffic control.

EXHIBIT 2-6: BASELINE CAPACITY

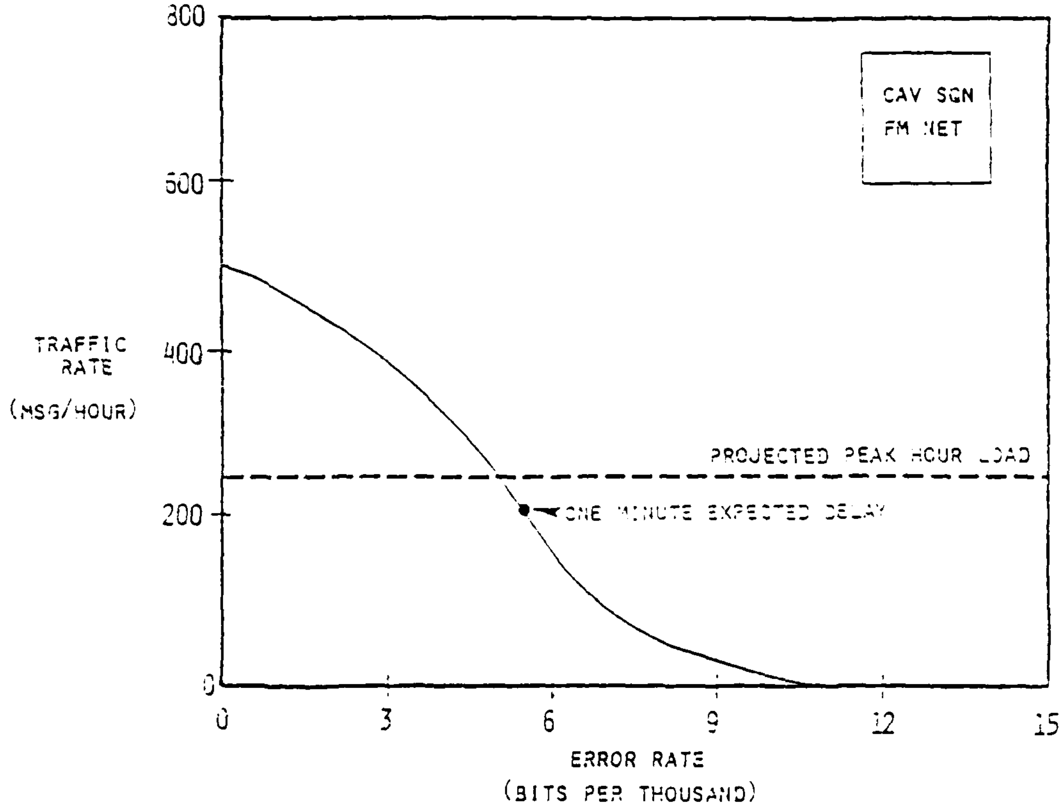


EXHIBIT 2-7: EFFECT OF RETRANSMISSION STATIONS ON CAPACITY

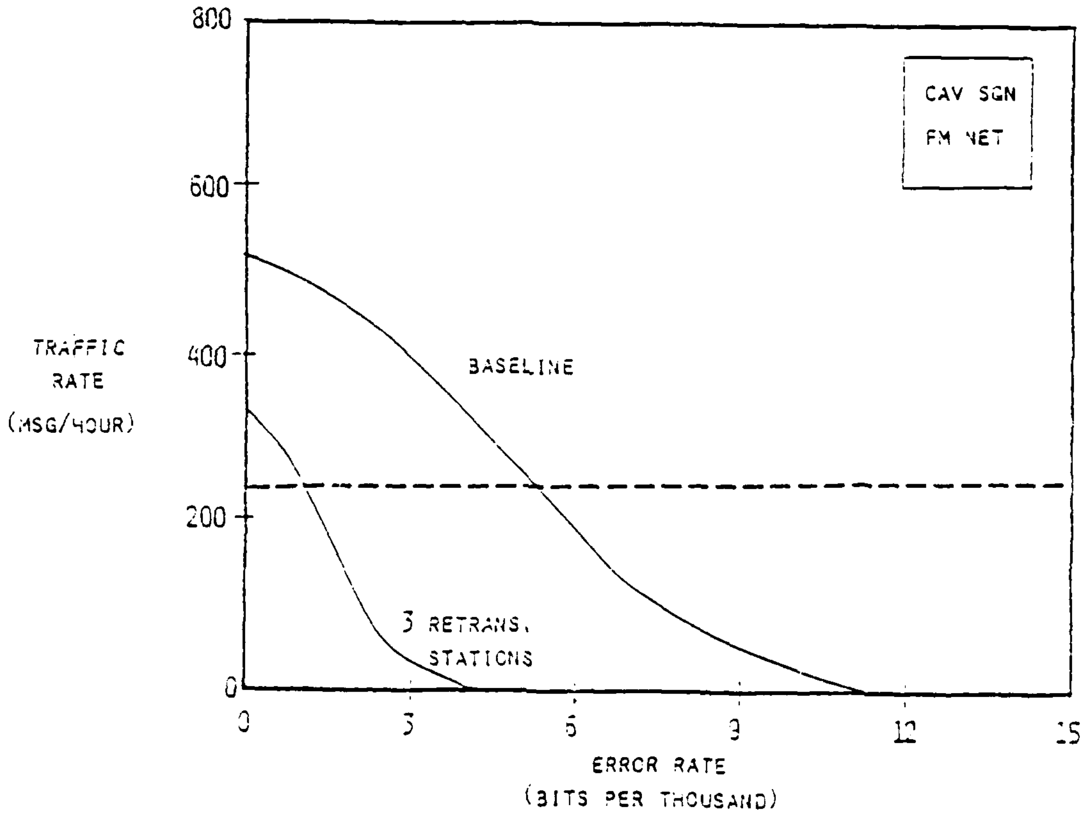
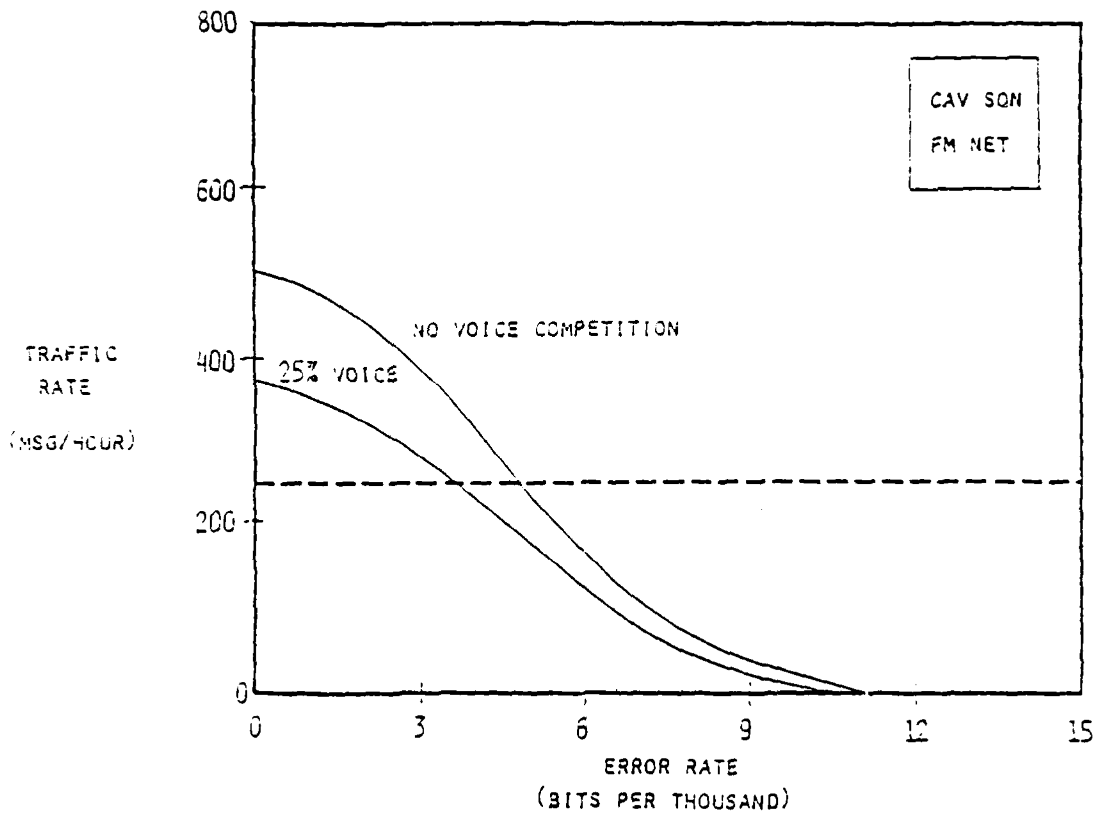


EXHIBIT 2-8: EFFECT OF VOICE COMPETITION ON CAPACITY



3.0 PROCEDURES FOR MANAGING A TOS SYSTEM OVERLOAD

At the termination of its development, the Tactical Operations System (TOS) was being designed as a computerized battlefield information system to be used by the division commander and his staff in support of tactical decisionmaking. The large volume of information available to such a system through use of modern data collection technology poses the potential of hardware and software overloads, particularly given necessary constraints in size due to considerations such as need for mobility and low vulnerability. Coupling this potential system constraint with the possibility of overloading the human users of the system with an inordinate amount of information which they are unable to assimilate led to the requirement for developing procedures for managing the use of TOS and its data base. These procedures are expected to be relevant to any TOS-like system which might be developed to support tactical decisionmaking.

3.1 INTRODUCTION

Information management procedures have been developed based on congestion analysis (summarized in the preceding chapter) of what might happen with a fielded TOS, the experience with FM-222 and general problems that occur with computer systems. These information management procedures are intended to maximize the availability of information from the system and to prevent or circumvent identified problems of system overload, storage overload, and user overload. The procedures include methods for monitoring and controlling the demands on the system, guidelines for performing system start-up and shut-down, and definitions for some of the data fields in message formats. This wide range of information management procedures is necessary for assuring that a high level of timely information is available and that TOS is continuously able to support the progress of the battle.

3.1.1 SCOPE

The purpose of this document is to describe how management procedures can be used to prevent or circumvent problems caused by excessive demands on the TOS system components--computer, communications, and user. Of the management procedures developed in phase I of this project,[5] those which are effective in controlling demand are: (1) control of the number of Incoming Message Retrieval requests; (2) operating levels; (3) purging; (4) removal of user(s) from distribution list(s);[6] and (5) hierarchical review. [In addition to

[5]Blum, et al., Information Management in the Tactical Operations System: Provisional Standard Operating Procedures (SOP), VRI-ARI-3 FR79-1, Vector Research, Incorporated, May 1979.

[6]The removal of user(s) from distribution list(s) was not explicitly suggested as a management procedure in the previous phase, but has since been identified as likely to be effective in addressing information problems. Misuse of the distribution list may cause unnecessary output to be sent to a user, resulting in a possible overload of a user and/or a communication link.

these procedures, the management procedures developed in phase I covered the topics of file management, user guidelines, and information processing during degraded modes of operation. These procedures provide the system user with guidelines for interfacing with specific features of the TOS system and are not particularly effective in controlling demand. For example, user guidelines includes guidelines for message preparation and for the definition of values for the message fields which have no prescribed contents. File management addresses the unique problems of each file.] Employment of one or more of these management procedures would reduce the demands placed on particular components of the system. The choice of which management procedure(s) to implement requires knowledge of the strengths and side effects of the procedures, knowledge of the cause of the problem, and knowledge of the information needs of each TOS user. This chapter provides information about the strengths and side effects of each of the five procedures mentioned above, and the data and related statistics (parameters which describe the cause of the problem) which need to be available to understand if a particular procedure would be effective in dealing with the problem. It is assumed that the person(s) responsible for controlling the system have knowledge of the users' information needs or that that knowledge can be easily obtained.[7]

The implementation of the procedures is discussed with respect to representative problems of system, storage, and user overloads. This discussion covers a method for choosing the management procedure or procedures to implement. The approach is through examination of the reduction in demand which can be realized by its implementation, and its possible effect on the quality of information processed through the TOS system. The purpose is to explain how the person(s) controlling the system can make effective management decisions in maintaining TOS or a similar command and control system in an operationally viable condition.

3.1.2 THE RESPONSIBILITY OF MANAGEMENT

The system controller (SYSCON) has overall responsibility for TOS computer center installation and displacement, TOS system configuration, and maintenance of the overall effectiveness of TOS computer operations. The SYSCON coordinates system initialization and shut-down activities and prepares the division computer center for relocation. Members of the system controller element monitor and control the data base, start and stop the system, monitor system status, and adjust priorities and processing schedules. The SYSCON is responsible for contingency procedures in the event of software failure and monitors the quality of software performance. The SYSCON coordinates the communications support for TOS with the division communications SYSCON.

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[7] Related research is being conducted on how people (commanders) make decisions and what information they use (information requirements) to make these decisions. See Methodologies for Determining a Decisionmaker's Information Requirements, a draft working paper by Greg Touma, Vector Research, Incorporated, 14 March 1980.

The function of the SYSCON as the overall manager of information processing in TOS is to coordinate the technical capabilities of TOS and the operational needs of its users. The restrictions imposed by the capacity of the data base storage devices and the processing times needed for transactions may require that limits be placed on the demands made on the system. The SYSCON is responsible for coordinating these demands with the capabilities of TOS. This requires that the SYSCON monitor each component of the system in order to diagnose the existence of a problem and understand the cause of the problem. In response to a given problem he may advise the file managers as to when they must act to reduce the size of their files, or instruct TOS users as to their permitted access to the system, or take action himself which will rectify the problem.

The SYSCON has the responsibility for managing the use of the TOS system and may task the file managers and TOS users to implement the management decisions. The extent to which the file managers and users are involved in the management of TOS would be a matter of local option and the specific problems which occur. The file manager's responsibility is to ensure that the contents of the file(s) delegated to him, however constrained in size or other technical characteristics, can provide maximum information value to the file users. The file manager coordinates with the SYSCON prior to taking any file action that might reduce system effectiveness, and warns the SYSCON of major anticipated changes in the space or processing requirements of the files. The users are instructed by the SYSCON on the access which they are permitted to the system. When problems arise which require that demands be decreased by one or more users, the affected user(s) may be involved in deciding how the reduction in demand is achieved (the choice among the management procedures), he (they) may be instructed as to which action to take, or the corrective action may be taken without any user involvement. Depending on the level of involvement users have in the management of TOS they may need to have knowledge of the status of TOS, particularly of the components which their demands impact, and the effects of each of the management procedures on both the quantity and quality of information. Involving the TOS users in the management of TOS would likely result in the users being more satisfied with the system, as they have the best knowledge of their information needs and how they use TOS to satisfy these needs. Another advantage of involving the user in the management of the system is that the burden on the SYSCON to perform this task should be decreased, particularly in the amount of monitoring which is necessary to make effective and acceptable management decisions.

In the discussion of the management procedures which follows, the SYSCON is assumed to be totally responsible for the management of TOS. This keeps the discussion of the task of management centralized and should make it easier to understand the complete process of management. It also draws attention to the fact that effective management of TOS is complex and requires extensive knowledge of the system, the battlefield situation, and the information needs of TOS users.

3.2 THE MANAGEMENT PROCEDURES

The purpose of this section is to discuss the five management procedures which have been identified as effective in addressing problems of overloads of TOS system components. For each procedure the topics covered are the purpose of the procedure, the procedure itself, the effect of employing the management procedure on the quantity and quality of messages processed by the system, and finally the information which needs to be available to employ the procedure. The effect of the procedure on quantity is measured as the amount of decrease in utilization (of the overloaded component) which can be expected given the procedure is implemented at some level.[8] Utilization of a computer processor (message disk controller and data disk controller) is calculated as the ratio of the amount of time required by the processor to perform the tasks demanded in a given time interval to the length of the time interval. Utilization of a communications link is defined as the ratio of the total length (in characters) of all messages transmitted over the link in a specific time interval to the maximum number of characters that link can transmit in that period of time.[9] The utilization of a user can be measured by a weighted combination of the total number of messages he composes and the total number of messages he receives in a given period of time, divided by the number it has been determined he can effectively assimilate in a period of time.[10] The discussion of the impacts of the management procedure on quality considers the effects of employing the procedure on the quality of messages sent or received by the users directly affected by the action and the quality of messages received by other users for whom the procedure did not directly impact. These quality effects are examined in terms of changes in the distribution of message types (SRI response, update messages, etc.) processed throughout the system. The information necessary to employ the management procedure are the statistics which need to be available to the SYSCON in order to choose the procedure or set of procedures which are most effective in correcting the overload.

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[8]In steady state analysis, utilization is defined as the fraction of time which the component is busy.

[9]The effect of transmission error is included in the number of messages transmitted over a given period of time. If a message is transmitted and received incorrectly, it will have to be transmitted again or deleted, effectively increasing the number of messages transmitted.

[10]The emphasis of this analysis was primarily on the system and storage overload problem. The user overload problem was addressed by empirical examination of the amount of messages each user composes and receives and the capacity humans have to assimilate information. This type of measure of the utilization of users appears to be reasonable for quantifying the overload problem, but the numerical values which are appropriate, as well as the appropriateness of this type of function, needs to be determined by further research, possibly through field experiments. Further discussion of the user overload problem is given in subsection 3.3.4.

3.2.1 PROCEDURE I: CONTROL OF THE NUMBER OF INCOMING MESSAGE RETRIEVAL REQUESTS

The Incoming Message Retrieval (IMR) requests include all the information processes which screen messages incoming to the DCC; specifically, SRIs (Standing Requests for Information), thresholds, correlations, and filters. As each message arrives at the DCC, message retrieval criteria are examined to determine if the message satisfies any set of criteria a user has specified. If the message does not satisfy any of the criteria, the message is retained in the system and no further processing occurs.[11] If the criteria are satisfied, one of the following four actions will occur:

(1) If the screening criteria are for an SRI, a copy of the message is sent to the originator of the SRI and other users specified on the distribution of the SRI.

(2) If the criteria are associated with a threshold, a search of the data base is triggered and records matching the threshold query are located. If the search is successful (the threshold specified is met) the originator is notified of the successful search and the incoming message which triggered the search. If the threshold is not met, no output is generated.

(3) If the criteria are associated with a correlation, a search of the data base is triggered via a query (a maximum of two queries may be initiated). The results of the query and the incoming message are sent to the originator; or

(4) If the screening criteria are associated with a filter, one of the following four things may occur: the incoming message is deleted; the incoming message is sent to the originator of the filter for review; a duplication query is initiated and if successful (a duplicate message found in the data base), the incoming message is deleted; or a duplication query is initiated and if successful, the message is sent to the originator of the filter for review. The result of review is either deletion or acceptance of the incoming message.

These functions provide a convenient way for TOS users to obtain their information requirements, but without careful construction of these requests and controls on the number and type of requests TOS users develop, some of the system components may be underlying burdened and vulnerable to overload.

Overloads of the computer processors may occur, particularly the message disk controller and the data disk controller, if the number of criteria which need to be examined are excessive, if the number of searches of the data base (due to the correlations, thresholds, and filters) are inordinate, or if the

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[11] If the incoming message contains entries in the distribution field, the message is distributed to those users.

data base is too large and too many records must be checked.[12] Overloads of the communications links may occur if the output load propagated by these requests is more than the communications net can support. Since the output from these requests is not directly controllable, as they are initiated automatically by TOS in response to incoming IMR messages from all sources, it is possible that unforeseeable changes in the input message stream may result in an increase in the amount of output generated and an overload of one or more communications links. This result may or may not be desirable to the involved user, and this phenomenon may also result in an overload of the user(s). A user overload may also occur if too many or too broad-range requests (an attempt to "cover all bases") are developed or if care is not taken in defining to whom the output is sent (unreasonable use of the distribution lists), resulting in unwanted information being sent to users. The procedure proposed here addresses the circumvention of these problems by controlling the number of these requests and reducing the number as needed in response to an increase in utilization of a system component.[13]

Controlling the number of requests that users establish not only promotes satisfactory system operation, but also motivates users to eliminate requests which are outdated and to consider the usefulness of a request before adding it to the system. The number of each type of the IMR requests an individual user is permitted to have in the system is based on consideration of the total number which the computer system can process and the relative information needs of the user.[14] The SYSCON will be required to reduce (or possibly increase) the permitted number of requests in the system in response to changes in user requirements due to changes in mission or in response to a degradation of the system resulting in increased utilization of a particular component. [In this document emphasis is placed on how management procedures can be used to rectify problems of overload; therefore, the implementation of the procedure is discussed from the aspect of reducing

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[12]The demand that is placed on the computer processors by the examination of the message retrieval criteria and the searches of the data base are dependent on the design of the software and hardware of the computer system. At this time, the occurrence of overloads of these processors by IMR requests is hypothesized.

[13]The increase in utilization may be due to factors such as those described which affect the demands placed on the components or because of environmental changes which affect the total "usable" capacity of the compnent. For example, the effect of environmental conditions on communications nets (see subsection 2.4).

[14]An examination of the demands placed on the system by projected peak hour message loads and the user requirement for the use of these IMR requests has shown that these requirements are satisfactorily met by the system as it was defined when work halted in November 1979. See Witus et al., Analysis of Information Flow in the Tactical Operations System, ARI Research Note 80-12.

the number of IMR requests in response to an identified overload. It should be relatively straightforward to see how this procedure could be used to increase the number of requests in the event that the state of the system allows increased use of the system.]

Once an overload problem is identified, a decision is required as to which type of IMR requests are to be deleted and in what numbers in order to obtain the desired effect on the utilization of the overloaded component. A reduction in any four of the IMR requests affects the user(s) to whom the responses are sent, the communications link(s) over which the responses travel, and the computer processors which handle the requests. The magnitude of the impacts on each of these components is dependent on the type of IMR requests, and therefore are discussed individually in the paragraphs below.[15] Included in this discussion of each type of request is the impact of a reduction in the number of requests on the quality of information processed by the system. The combination of the effects of implementing the procedure on quantity and quality provide the SYSCON with a basis on which to make a decision as to whether or not to implement the procedure. The decisionmaking process is discussed with respect to specific system overload problems in section 3.3 following a discussion of the four remaining management procedures.

Standing Request for Information (SRI)

The magnitude of the effect of a reduction in the number of SRI on a user is simply the number of response messages which the user will no longer receive from the SRI which are deleted. The decrease in the utilization of the communication nets over which the SRI responses travel is a combination of the number of responses which are deleted, the length of the response in characters, and the number of times the response would have to be transmitted in order to be received correctly (the effect of errors in transmission). The decrease in utilization of the message disk controller is determined by the number of SRI which would be matched by an incoming message and the number of users to whom the response would be sent. Finally, the effect on the data disk controller is the number of times the SRI which are deleted would have been checked against incoming messages which in turn is dependent on the characteristics of the input stream. For a system based on estimates provided by the system A- and B-level specifications, the effect of decreasing the number of SRI by 50 percent on five of the system components is given in exhibit 3-1.

The effects on the quality of information from SRI are determined by the value of the SRI responses to the users. If the responses are distributed to more than the originator of the SRI, the value of the response to these users must be considered also. Other impacts which are equally difficult to quantify are the degree to which users may employ other information processes;

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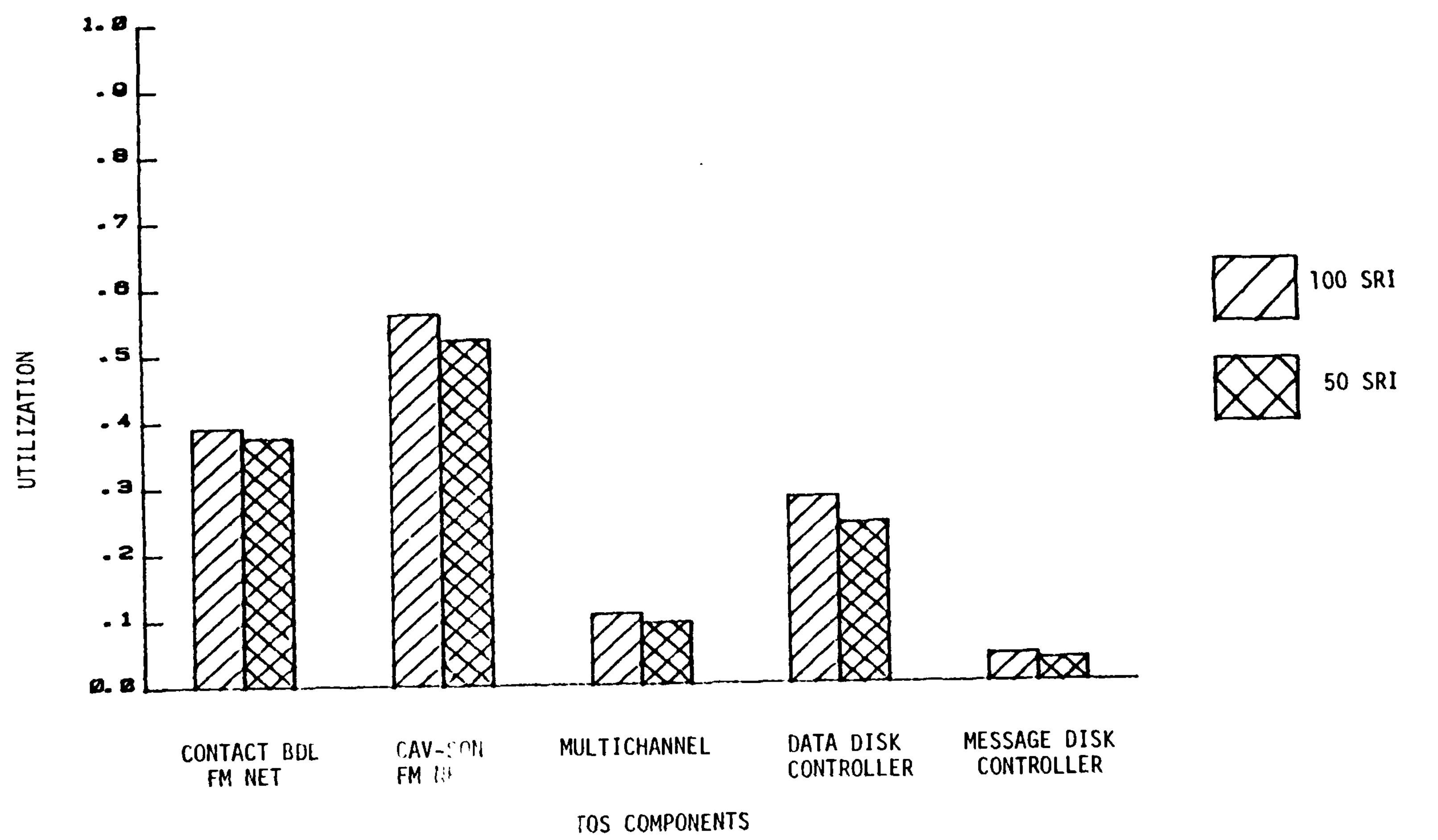
[15]The magnitude of the impact is also dependent on the software design and performance capability of each component. In the discussion which follows, the impact is based on analysis of the TOS system as it was defined and documented in November 1979.

EXHIBIT 3-1: EFFECT OF A DECREASE IN SRI ON TOS COMPONENTS



for example, queries to obtain the information they no longer receive from these SRI, and the magnitude of the resulting increases on utilizations of the TOS system components.

Thresholds

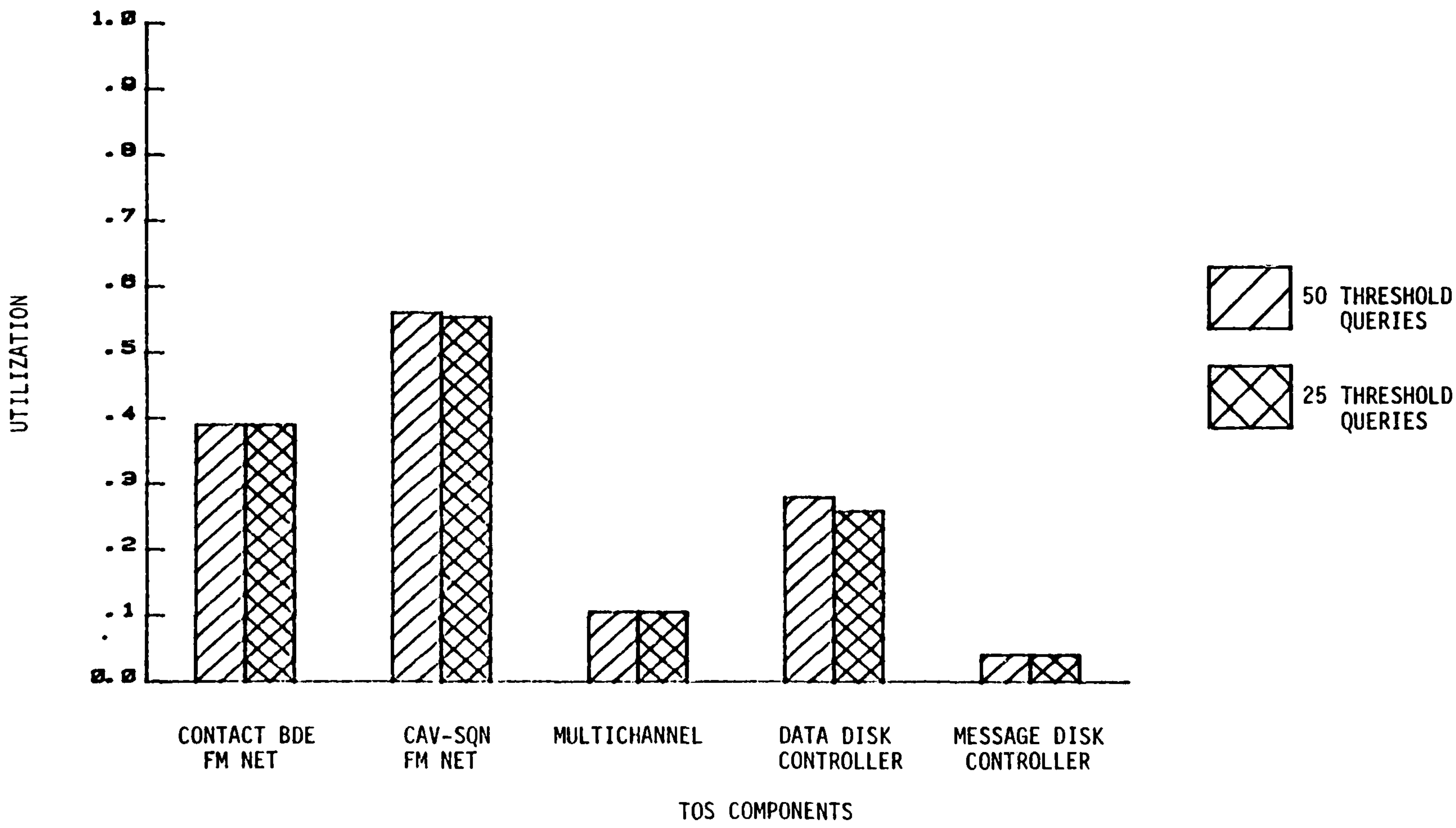
The threshold function is used primarily by intelligence analysts for automated message processing. The use of the function is not much of a burden to the system users as the output is expected to be short and infrequent. The magnitude of a decrease in number of thresholds on utilization of a communications link is similarly small as seen in exhibit 3-2. The factors which determine the magnitude are the number of responses which are eliminated as a result of the deleted threshold requests and the length of the response. The effect on the message disk controller is also not substantial as factors which determine the impact are the number of responses generated by the threshold and the number of people to whom the output is distributed; which is likely to be only the originator of the threshold. The greatest impact of a reduction in the number of thresholds is on the data disk controller which handles all the accesses to the data base to determine if the threshold query is triggered and then determines if the threshold is met. The factors involved in estimating the magnitude of reduction in utilization of the data disk controller are the number of threshold requests which are deleted, the frequency with which they are triggered, and, for those triggered, the number of keys and key values specified by the threshold query.

The quality considerations involved in deleting some threshold requests include not only the value intelligence analysts place on the information received from these requests, but also the impact on the products of their analyses. The threshold function provides a means by which analysts can process data records into information and intelligence which is more complete, accurate, and meaningful. This can improve the general quality of information processed by the system and may also decrease the size of the data base, eliminating redundant data records and combining others.

Correlations

Like the threshold requests, correlations are also primarily used by intelligence analysts for automated processing of data. The output to these users from a correlation are data records or some type of computer-generated report which provides the results from the automated query (queries) triggered by the correlation and the incoming message. This output may be quite lengthy and difficult for a user to assimilate, especially if not in a report format; therefore, users should be careful as to the construction of these correlation requests. The effect of reducing the number of correlation requests on a user is simply the elimination in the messages they would have generated. The factors which affect the magnitude of the decrease in utilization of the communications link over which the response travels are the frequency that the correlations which are to be deleted would have been triggered, the length of the output in characters generated by these correlations, and the number of times the output would have to be transmitted in order to be received

EXHIBIT 3-2: EFFECT OF A DECREASE IN THRESHOLD QUERIES ON TOS COMPONENTS



correctly by the receiving node (effect of transmission errors). As with thresholds, the magnitude of the effect on the message disk controller of a decrease in the number of correlations is expected to be small because the number of times a correlation is triggered is expected to be infrequent and the distribution of the output is likely limited only to the originator of the correlation request. The greatest impact of a decrease in the number of correlations is expected to be seen on the data disk controller. The factors which determine the magnitude of this decrease are the number of correlations which are deleted, the frequency with which the message retrieval criteria associated with these correlations would be tested, the frequency with which the query (queries) associated with these correlations would be triggered, and the number of keys and key values specified in the query (queries).

The impact of a reduction in the number of correlations on the quality of information processed by the system is expected to be like that described for thresholds. Briefly, the considerations are the value of these responses to the users and the impacts which may be seen in the quality and quantity of information stored in the data base.

Filters

The filter requests are originated by file managers to control the quantity and quality of information added to their file(s). This function gives the file managers the ability to check messages for accuracy, completeness, and redundancy. The magnitude of the effect on the user of a decrease in utilization of filters is determined by the frequency with which the deleted filters generate output. A reduction occurs both in the input from and output to the user because action is required by the user either to approve or delete any message screened by the filter. A reduction in the utilization of communication links over which the responses travel is determined by the frequency with which the filter generates output, the length of the output, the length of the response generated by the user to the filter output, and the number of times the filter response and the user response would have to be transmitted in order to be received correctly at the intended receiver node. Since the filter responses are expected to be short in length, relatively infrequent, and distributed only to the originator of the filter, any reduction in the number of filters results in a relatively small decrease in the utilization of the user and the communication nets. Similarly, a small decrease in the utilization of the message disk controller is expected as a result of a decrease in the number of filters, as the factors which determine the magnitude of the effect are the frequency with which output would be generated by these filters and the number of users to whom the output would be distributed. The magnitude of the effect of a decrease on the utilization of the data disk controller is rather complex as the function permits the user many alternative actions. The factors which must be considered in determining the magnitude are: the number of filters to be deleted and the frequency with which the associated message retrieval criteria would be tested; the frequency with which these criteria would be satisfied so that a data base search is required; and the number of keys and key values associated with that search. A significant decrease in utilization of the data disk controller may be obtained by a decrease in the number of filters.

A reduction in the number of filters would primarily decrease the quality and increase the quantity of data stored in the data base. These changes may require an increase in the amount of purging needed to maintain the data base and decrease TOS user satisfaction when he queries the data base. In addition, the filters decrease the number of input messages distributed to users and reduction of the filters would likely increase the load on the users, system, and communications links. Consideration should be given to this factor when selecting the filter to delete.

In response to an identified overload at a particular component, the SYSCON might choose to reduce the number of IMR requests in the system. The decision as to which type or types and the amount would depend on the quantity and quality factors described above and the number of each of these in the system at the time. The statistics which need to be available to the SYSCON in order to assess the impacts on quantity and those associated with factors described above are given in exhibit 3-3.[16] The SYSCON is assumed to have knowledge of the battlefield situation and users' information needs. Given the component which is overloaded and the characteristic of the overload, the SYSCON can use these statistics to determine the reduction in a particular type IMR request that is required in order to rectify a problem and whether or not that reduction would be acceptable to the TOS users.

3.2.2 PROCEDURE II: OPERATING LEVELS

The concept of operating levels has been developed to provide a means to coordinate user demands (data base updates and queries) with the operating status of TOS. They are tools by which the SYSCON can guide TOS users to respond to changes in the status of TOS due, for example to a communications net overload. Operating levels are a pre-defined set of constraint values on the number of update and query messages a user can place in the system. For example, using a 4-level system, a TOS user may be given the following set of parameters for each level:

Level	No. Queries per Hour	No. Updates per Hour
A	20	30
B	10	20
C	5	10
D	0	0

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[16] These statistics are assumed to be available to the SYSCON either automatically, by querying the data base for the component data, or by surveying users and file managers for the appropriate information and performing the necessary calculations.

EXHIBIT 3-3: MONITOR STATISTICS FOR INFORMATION RETRIEVAL REQUESTS [1]

SRI	THRESHOLD	CORRELATION	FILTER
Number of SRI in system, by originator.	Number of thresholds in system, by originator.	Number of Correlations in system, by originator.	Number of filters in system, by originator.
Frequency that IMR criteria for SRI are checked (characteristics of input arrival stream).	Frequency that IMR criteria for thresholds are checked (characteristics of input arrival stream).	Frequency that IMR criteria for correlations are checked (characteristics of input arrival stream).	Frequency that IMR criteria for filters are checked (characteristics of input arrival stream).
Frequency that IMR criteria for SRI are satisfied.	Frequency that IMR criteria for thresholds are satisfied.	Frequency that IMR criteria for correlations are satisfied.	Frequency that IMR criteria for filters are satisfied.
	Frequency that threshold criteria are satisfied.	Average number of queries triggered.	Frequency that a data base search is triggered.
			Frequency that a response is sent (with or without a data base search).
	Average number of keys and key values searched.	Average number of keys and key values searched.	Average number of keys and key values searched, if data base search is required.
Distribution of SRI responses.	Distribution of threshold responses.	Distribution of correlation responses.	Distribution of filter responses.

[1] These statistics can be monitored for the system as a whole, then extended to apply for each individual request to estimate the effect of each management procedure on utilization.

At level A, the TOS user would be permitted to transmit 20 queries per hour and 30 updates per hour; whereas, at level C he would be restrained to transmit at or below a rate of 5 and 10 per hour, respectively. In general, the level of operation may be associated with a level of system operability in the sense that at level A the system would be operating satisfactorily; hence, the level defines the maximum allowable rate of demand by a user. Similarly, at level D operation, no TOS interaction would be permitted if, for example, the Division Computer Center (DCC) had crashed. Levels B and C define intermediate levels of use. In response to an identified overload the SYSCON may choose to decrease the utilization of the component by lowering the operating level of one or more users. The magnitude of the effect on the user is the difference in number of update and query messages between the current level of operation and the lower level. In addition, a decrease would also be seen in the amount of output that user receives due to the reduction in the number of queries. The magnitude of the decrease in utilization of the communication net over which the user's inputs travel would depend on the decrease in the number of inputs (updates and queries) and the length of these inputs, the number of queries and the length of the responses to these queries, and the number of times which these messages would have to be transmitted over the communications link in order to be received correctly at the receiver node. The effect of a decrease in operating level on the message disk driver is dependent on the reduction in the number of updates and queries, and the distribution of output associated with these demands. The effect on the data disk controller depends on the reduction in number of updates and the number of keys in the inverted key buffer which must be updated, and the reduction in the number of queries and the number of keys and key values which must be searched to satisfy the query. Indirect effects on the utilization of other users, the communication links, and the message disk and data disk controllers can be expected because of changes in the message stream which the IMR requests act upon.

Two basic considerations with respect to quality need to be addressed before a decision is made to decrease the operating level of user(s). First is the value of the update--add and change--messages submitted by the user(s) to the rest of the division. Secondly, the value of the prohibited queries to the user(s) whose operating level is decreased needs to be considered.

The SYSCON's decision to decrease the operating level of a user would reflect the value of the decrease in the utilization of the overloaded component relative to the value of the information lost to that user and to the division as a whole. The statistics which need to be available to the SYSCON in order to estimate the decreases in utilization of the overloaded component obtained by decreasing the operating level of one or more users are given in exhibit 3-4. How the SYSCON can use these statistics to determine which user or users would be affected and the level of decrease necessary in order to obtain the desired reduction in utilization is discussed in subsection 3.3 where the employment of management procedures is discussed in the context of a particular component overload.

EXHIBIT 3-4: MONITOR STATISTICS AND GUIDELINES FOR OPERATING LEVELS

USER	CURRENT OPERATING STATUS			OPERATING LEVEL GUIDELINES (UPDATE/QUERY)			
	UPDATE RATE	QUERY RATE	DEFINED OPER.LEV.	A	B	C	D
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•

3.2.3 PROCEDURE III: PURGING

Purging removes outdated and irrelevant records from the data base. Continually, existing records are updated and other records are manually purged as new and/or more accurate data are obtained. From correlations, thresholds, and filters, records are manually summarized or eliminated. Querying provides users with the capability to retrieve information from the data base. With that information, the battlefield is assessed, plans are made, etc. During this constant use and review of the data base, redundant, irrelevant, and inaccurate records should be identified, and users would be expected to delete them.

The maintenance of TOS files may require that additional records be deleted to ensure the quality of the files and, more important operationally, to ensure that the data base does not become overloaded and that there is storage available for new messages as necessary. The SYSCON will advise file managers of the technical constraints on the growth of files, and in response to estimates of the future size of files, file managers are expected to purge their files. The individual characteristics of each [illegible] will determine exactly what data in the files are candidates for pur[illegible] considering their timeliness and relevancy to the battlefield situation, yet the methods of purging can be standard for all files. Three methods of purging--automatic, routine, and "as required"--have been identified as means to manage the size of the TOS data base. Individual divisions and their file managers should adapt some form or combination of these methods to meet unique local requirements.

The automatic purge is a query or set of queries stored in the Preloaded Message (PLM) file which is automatically implemented periodically to search the Enemy Situation Data (ESD) file. Messages matching the query criteria are deleted. The frequency of the search and the criteria on which to base the search are defined by the ENSIT files manager. The prime candidates for deletion by this method are those records whose validity depends on time, since implementation of the automatic purge is periodic. The age at which the message becomes outdated can vary for each automatic purge query established.

The routine purge requires periodic review of selected data records and the deletion of unneeded data in quantities great enough to maintain a satisfactory operational system. Although the frequency of review depends on the file manager and the file, routinely, file managers or delegated users should query the data base to delete records which have become irrelevant due to time and retrieve and review for deletion records which are otherwise no longer useful. The criteria on which data are purged reflect a combination of the commander's information needs and the system status. Deleted records will have been judged too costly (in terms of use of storage space) to keep in the data base. Not only will this reduce the size of the files but also aid in maintaining the quality of the data base.

"As Required" purging is determined by system monitoring. This purge should be implemented only when there is an indication that a file size is too large or an indication of an impending overload which requires the file(s) to be reduced. The need to purge could result from a change in the message input rate, operating level, tactical situation, etc., which was not known

at the last scheduled routine purge. The SYSCON should direct the appropriate file manager to reduce the size of the data file. The system status will dictate the volume of data needed to be purged to circumvent or rectify the overload. The records to be purged can be obtained by calling a stored query, or by constructing an ad hoc query to be certain the number of records retrieved is sufficient to meet the required volume reduction. The selected records can be automatically deleted or reviewed for possible deletion.

Purging can be based on one, all or any combination of the three methods. The continual automatic and periodic purges are effective in maintaining a data base of quality information which is likely to impact system users. The primary system effect of purging is on the size of the data base. The SYSCON and file managers need to know the size and growth rate of each file so that when the data base is to be purged, a purge can be implemented such that the data base is returned to an acceptable size with minimal impact on the quality of the holdings. "As required" purging is done when special needs are to be met or as unrecognized growth in the data base has caused the storage to be overloaded. The SYSCON needs to monitor the size of each of the files and alert the file manager(s) as to when they are becoming too large. Further, the SYSCON and file manager(s) will need to be aware of the amounts and types of messages contained in these files in order to be sure that the purge is effective and timely in reducing an overload state.

An indirect effect of purging the contents of data base files is a reduction in the amount of output generated via correlations, thresholds, queries, etc. This effect should be minimal if the purge is automatic or routine, as the information which is deleted is likely to be no longer useful and consequently not included by the retrieval criteria. In the case of an "as required" purge, the effect could be significant.

3.2.4 PROCEDURE IV: REMOVAL OF A USER FROM A DISTRIBUTION LIST

Distribution lists (D/L) provide TOS users who wish to send messages to a variety of users with a means to do so without having to type the destination code for each user. A D/L contains as many as 20 destinations and is given a unique name by which it is identified. The D/L are created and modified only by the SYSCON and file manager(s) and therefore it is easy for the SYSCON to control and monitor who is contained on each D/L.

Users should be kept aware of the distribution lists which are available and the subscribers to the lists so that when they are used the message is sent to those users who need the information and only them. Misuse or abuse of the D/L may occur if the lists change often or if users are not careful to choose a D/L which contains, as nearly as possible, only those users who need the message. Otherwise, the result can be an overload of many users because they receive irrelevant messages or an overload of the communications net because of the unnecessary output propagated by these lists. A problem with controlling the type and amount of output propogated by D/L is that the receivers are not in control of what is sent to them; the originator of the message enters the D/L name and the message is automatically distributed.

The characteristics of the construction and use of D/L make them effective in addressing problems of overloads, whether or not they are identified as the root cause of a problem. The SYSCON can remove a destination address from one or more D/L in order to reduce the DCC output load, most likely resulting in a reduction of the demand placed on users to assimilate the output messages, the communication links over which the messages travel, and some of the computer processors.[17] The magnitude of the effect on a user is dependent on the frequency with which he would receive messages via the D/L from which he is to be removed. The effect on the communications net over which those messages would be transmitted depends on the frequency and the length of the messages. The only computer processor which is affected by the use of D/L is the message disk controller which will write the message to the message disk for every user to whom it is sent. The magnitude of the effect is therefore dependent on the frequency with which the D/L from which the user is to be removed is entered in the distribution field of a message.

The information quality issues are primarily limited to the value of the messages the user receives via the D/L from which he is to be removed. If only particular types of messages received via D/L are of value to a particular user, the originators of those messages can be advised of the change and have that user identified explicitly as a destination. Alternatively, the user could submit an SRI which will screen those messages for him.

In order to employ this management procedure effectively, the statistics which are given in exhibit 3-5 need to be available to the SYSCON. Depending on the component which is overloaded, the SYSCON would need to determine which user or users should be removed from which D/L in order to be assured the necessary amount of utilization reduction would be attained once the procedure is implemented.

3.2.5 PROCEDURE V: HIERARCHICAL REVIEW

The hierarchical review process allows the brigade element to review, for possible alteration or deletion, messages originating at a subordinate battalion. If a message is changed or deleted, a copy of the message is sent to the originator. Hierarchical review, therefore, may be a contributor to an overload problem as well as a procedure to circumvent a problem. The process reduces demands placed on the communications link between the DCC and the BDE, as some messages may be deleted by the review. Consequently, the demands on the computer processors are also reduced as the arrival rate of messages is decreased. Alternatively, the communications net between BN and BDE are further burdened by hierarchical review due to the notification sent to the originators of deleted or altered messages. Therefore, altering a hierarchical review practice may be helpful in addressing an overload problem.

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[17]The demands placed on the computer processor by the use of D/L on messages is dependent on the design of the system software. The assumption made in this analysis can be used only for illustration of possible impacts.

EXHIBIT 3-5: MONITOR STATISTICS FOR CONTROL OF DISTRIBUTION LISTS

USER	OUTPUTS TO USER		DISTRIBUTION LIST (X IF USER-CONTAINED)						
	NUMBER RECEIVED	NO. RECD. VIA D/L	1	2	3	4	5	6	....
•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•

Depending on the component which is overloaded, the review procedure may be altered to increase or decrease the frequency with which messages are to be reviewed. In order to determine if the procedure would be effective in addressing a problem, the SYSCON would need to know the frequency at which the messages originating at BN are reviewed at BDE (for each BDE), the frequency at which those messages are changed, and the frequency at which they are deleted. The magnitude of the effect of implementing the procedure on the utilization of BDE-BN and the BDE-DCC communications nets depends on the amount of increase or decrease in the frequency of messages reviewed, the length of the response to the originating BN when a message is altered or deleted, and the length of the original message. The magnitude of the effect on the computer processors depends on the increase or decrease in the infrequency at which messages are reviewed and the types of message which are effected (queries, additions, etc.).

Before a current hierarchical review practice is altered, the SYSCON should consider the "side effects" of the alteration. With respect to quantity, the SYSCON should realize that an alteration to decrease demand on the BDE to DCC communications net increases the demand from the BDE to BN and vice versa. With respect to quality, the hierarchical review process increases the quality of messages in the system by providing for more complete and accurate information. Any attempt to decrease the level of hierarchical review may have as its consequence a degradation in the quality of the information received at division and can have a variety of impacts on other users of that data (e.g., increased purging to delete the "poor" information, increased querying to verify the information obtained, etc.).

3.3 INFORMATION MANAGEMENT PROBLEMS

The procedures discussed in the preceding section are tools the SYSCON can use to control the quantity of information transmitted and stored by TOS. The purpose of these procedures is to reduce an overload at a component of TOS. The components which have been identified as the most vulnerable to an overload are the communication links (especially FM and multichannel), the computer processors (particularly the message disk controller and the data disk controller), and the data base disk storage.

Depending on the component which is overloaded, the SYSCON would have a choice within the set of five management procedures for a procedure(s) which could best alleviate the problem. For example, a storage overload is perhaps most quickly alleviated by purging, but also may be resolved by decreasing the operating levels of users. The choice among these procedures as to which are most effective depends on the circumstances causing the overload, the consequences of the overload, the current battlefield situation, and the role of TOS in supporting the mission. Consequently, the SYSCON must have knowledge of all of these factors and be able to determine the effects of each procedure on the overloaded component as well as the effects on success of the mission and the satisfaction of the users.

The purpose of this section is to describe problems which may occur and how to determine which procedure is most effective in circumventing which problem. It is assumed that the SYSCON can monitor all the statistics mentioned in the previous section,[18] and that he has knowledge of each user's role in the battle. This allows the SYSCON to make effective TOS management decisions which are in the best interests of the division.

The problems and associated management solutions are described in four subsections depending on the system component involved. In subsection 3.3.1, communication net overloads are discussed, and the example used is an overload of an FM link between BDE to BN. Subsections 3.3.2 and 3.3.3 address overloads of computer-related components: the computer processors and disk storage. Control of an overload of the data disk controller is used as the example pertaining to a computer processor overload. Finally, in subsection 3.3.4, management in response to an overload of a TOS user is described. For each problem, the management procedures are identified which may be effective in addressing the problem. Then, by considering the conditions causing the overload, the effectiveness of these management procedures in dealing with the overload is determined in terms of reducing the utilization of the component (quantity). Finally, the implications of each of these management procedures on the quality of information and on the permitted user access to TOS are overlaid on the quantity impact in order to decide which management procedure(s) to employ. By stepping through the analysis example for each of these problems, the considerations which are necessary to make effective management decisions should become evident and can then be applied to other component overload problems.

3.3.1 COMMUNICATIONS NETS

The supporting communications for TOS are the FM and multichannel nets and the cable links over which messages are transmitted from a TOS user I/O device to the computing center and vice versa. An overload on a communications net will likely increase the length of time a user waits for a response to a query or decrease the rate at which he receives messages from other users. If the net which is overloaded is his own, the TOS user may experience an increase in receipt of NAK (nonacknowledgements) or extreme difficulty in obtaining the net for transmitting messages. This frustrates the user because TOS cannot meet his demands, and when it does, the response is untimely.

A communications overload is due to a demand on the communications net to transmit more messages than it can support. The source of those messages may be direct inputs (update and query) from a user, responses to information retrieval requests, or relay messages among subdivided users. Also, communications nets are susceptible to transmission errors caused by electronic

[18]This assumption is the central topic of chapter 4.0.

countermeasures, environmental noise, and hardware errors. This greatly affects net capacity (the ability to transmit messages correctly) and, consequently, the communications system may be unable to support even modest demands.[19,20]

The management procedures which are most likely to be effective in dealing with a problem of communications overload are procedures I, II, and IV above, specifically, control of the number of Information Retrieval Requests, Operating Levels, and Removal of a User from a D/L. In the case of a BDE FM communications net, procedure V--Hierarchical Review--may also be effective in dealing with some problems of overload. Once the overload is identified, the SYSCON must quickly analyze the situation and implement the appropriate management procedures to circumvent the problem.

Given that the SYSCON has knowledge of the contribution to the overload of each transmitter-receiver pair utilizing the net, the types of messages which compose the load, the importance of each user's access to TOS and to the success of the mission, and the importance of each type of message to the users, he can determine the impact of implementing each of the management procedures on the utilization of the overloaded component and on the information needs of the users whom the procedure would effect. The SYSCON then must decide on and implement the appropriate procedure or procedures.[21]

An Example: Overload Of A BDE-BN FM Net

For this example consider that an overload of a BDE-BN FM net has been identified. The configuration of this net is given in exhibit 3-6. The net is shared by eight transmitter-receiver pairs, one at each battalion and four at brigade. The SYSCON is assumed to have available the statistics given in exhibits 3-7 and 3-8 which characterize the utilizations of each of the users (transmitter-receiver pairs) who access the net.[22]

Imagine that the SYSCON has determined that the utilization of this net should be maintained at or below 0.700. From the figures in exhibit 3-8, the current utilization has been measured at 0.859 with the three maneuver battalions contributing over 80 percent of this utilization. Observe from

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[19]Capacity here is defined as in chapter 2.0: "Component capacity is the traffic rate which results in 80 percent utilization."

[20]For a further discussion of these effects see ARI Working Notes 80-12 described in the preface.

[21]It is possible that circumstances may exist for which the SYSCON decides it is best to do nothing and let the communications net continue in the overloaded state.

[22]The means by which these statistics are made available is not yet known, but it is assumed that if they are not automatically generated the SYSCON can either query the system or the users for the information.

EXHIBIT 3-6: CONFIGURATION OF BDE-BN COMMUNICATION SYSTEM

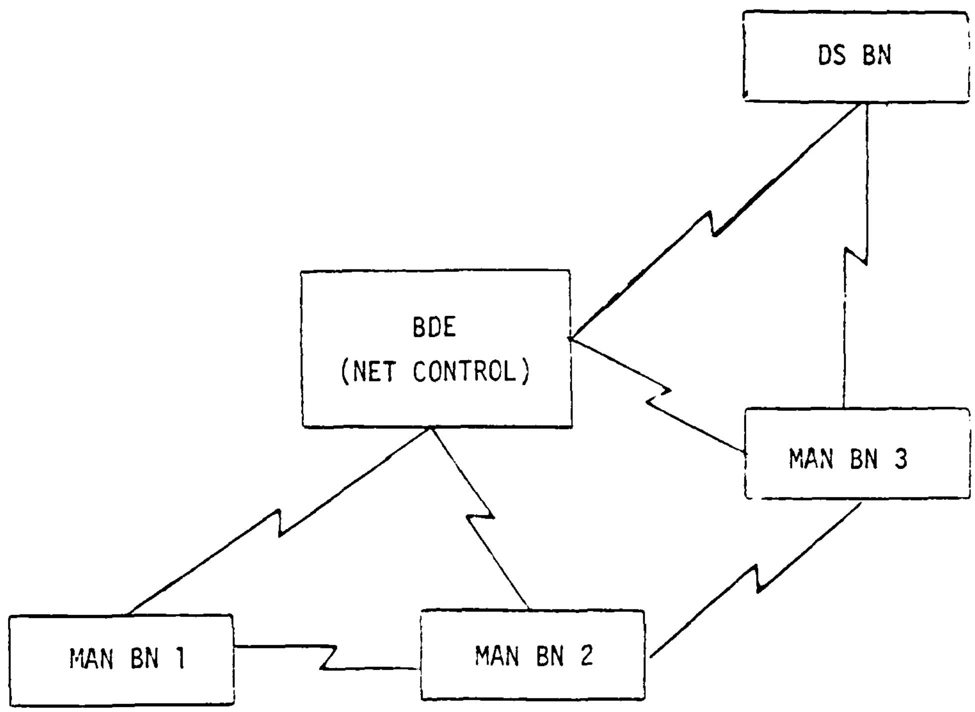

EXHIBIT 3-7: EXAMPLE LOADINGS ON THE TOS COMPONENTS OF A BRIGADE

*Circle indicates current operating level.

USER	OUTPUTS PER HOUR						NUM OF D/L	MSGS	INPUT PER HOUR	INPUT/ OUTPUT PER HOUR	OPERATING LEVEL DEFINITION*			
	IMR RESPONSES (IMR REQUESTS ORIGINATED)				UPDATE RESPONSES (TO BNs)			ALTER/DEL	UPDATE		UPDATES/QUERIES PER HOUR			
	SRI	THRESH	CORR	FILTER	TOTAL	VIA D/L	A MEMBER OF	BY H/R	TO DCC	QUERIES	A	B	C	D
BN 1:														
TRANS									39	6	40/10	30/5	12/3	0/0
RECVR	9				11	11	4	4		6				
	(2)													
BN 2:														
TRANS									39	6	40/10	30/5	12/3	0/0
RECVR	9				11	11	4	4		6				
	(2)													
BN 3:														
TRANS									34	6	35/10	30/5	12/3	0/0
RECVR	9				11	11	4	8		6				
	(2)													
DS BN:														
TRANS									26	4	30/10	25/5	9/1	0/0
RECVR	1				6	6	2	10		4				
	(2)													

EXHIBIT 3-8: CALCULATED UTILIZATIONS OF BDE-BN FM COMMUNICATIONS LINKS[1]

LINKS UTILIZING BDE-BN FM NET	UTILIZATION OF NET
BN1 Transmissions to BDE	0.198
BDE Transmissions to BN1	0.042
BN2 Transmissions to BDE	0.198
BDE Transmissions to BN2	0.042
BN3 Transmissions to BDE	0.177
BDE Transmissions to BN2	0.048
DS BN Transmissions to BDE	0.132
BDE Transmissions to BN3	0.025
TOTAL BN Transmissions to BDE	0.703
TOTAL BDE Transmissions to BN	0.156
TOTAL	0.859

exhibit 3-7 that the types of messages which comprise this utilization are primarily input messages (queries and updates) as indicated by the utilization of the brigade FM communications net for transmitting messages originating at the subordinate battalion.

From the statistics assumed to be available to the SYSCON as given in exhibit 3-7, the potential for each management procedure to decrease the utilization of the brigade FM net can be calculated and is given in exhibit 3-9.[23,24] This potential is the maximum decrease in utilization which could be achieved by a given procedure if it were invoked to its limit, for example, if the operating level of every user were reduced to level D (0 updates and 0 queries). In terms of quantity only, the most precipitously effective management procedure would be to change the operating level of all users to level D which would result in a decrease of 0.703. The management procedure which has the least potential for rectifying the overload problem is altering the hierarchical review such that no messages are reviewed (i.e., no messages are deleted or altered and therefore, no notification is sent to the originators). Also shown in exhibit 3-9 is the potential decrease which can be obtained if the procedure is applied to only one of the battalion. A detailed explanation of exhibit 3-9 and its impact on the example is in order. Referring to the exhibit, a number shown in parentheses in the "total" column is the decrease in utilization which can be achieved per "unit" change in the management procedure, where "unit" is defined with respect to the management procedure. In the case of the first management procedure, the "unit" is one IMR request--SRI, THRESHOLD, CORRELATION, OR FILTER. The load statistics given in exhibit 3-7 show that each MAN BN has two SRI in the system and receives nine responses per hour and that the DS BN has two SRI and receives one response per hour (a total of eight SRI requests and 28 SRI responses from the four battalions). From exhibit 3-9 the utilization of the net due to these 28 responses has been estimated to be 0.037. If one of these SRI requests were eliminated, an expected 3.5 (28/8) responses would be eliminated and a 0.004 (0.037/8) decrease in utilization would be achieved.

The "unit" for management procedure II is one query or update message. To determine the expected effect of decreasing the operating level, the decrease in the number of queries and update messages to be expected need to be computed and then multiplied by the value of each of these "units." For example, if the operating level of BN1 was reduced from level A to level B, nine updates (from 39 to 30 in exhibit 3-7) and one query (from six to five) would be eliminated per hour, reducing the utilization of the net by 0.044 (10 X 0.0044, the latter factor shown rounded off to 0.004 in exhibit 3-9).

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[23]The equations for calculating the utilization of the net based on the monitored statistics given in exhibit 3-7 are given in the appendix. It is not useful to present them in this discussion as they are lengthy and cumbersome. It is the opinion of the authors that in reality the SYSCON will not be able to perform these calculations and that a Design/Decision Aid (computerized) will need to be used.

[24]Exhibit 3-7 gives the monitor statistics which are directly applicable to the BDE-BN FM net. The SYSCON will also need to have knowledge of the statistics discussed in section 3-2 and given in exhibits 3-3 and 3-5.

EXHIBIT 3-9: QUANTITATIVE EFFECT OF MANAGEMENT PROCEDURES ON EXAMPLE BRIGADE FM NET

MANAGEMENT PROCEDURE	DECREASE IN UTILIZATION FRACTION*				
	TOTAL	BN1	BN2	BN3	DS BN
I. Reduce IMR Requests	.037 (.004)	.012	.012	.012	.001
II. Change Operating Level	.703 (.004)	.198	.198	.177	.132
III. Purge	Not Applicable to Communication Problem				
IV. Remove User From D/L	.063 (.004)	.018	.018	.018	.009
V. Alter Hierarchical Review	.013 (.001)	.002	.002	.004	.005

*Sum may not add to total due to rounding.

For procedure IV, the unit is one D/L address. The utilization of the net due to update response messages received by D/L has been determined to be 0.063 as shown in exhibit 3-9. The MAN BNs are on four D/L and the DS BN is on two D/L resulting in a total of 39 update response messages (determined as the sum of the update response messages being received via D/L as indicated in exhibit 3-7) to be received by these BNs. From these statistics, the decrease in utilization which can be expected by the removal of one BN from one D/L can be determined and is estimated to be 0.004 (0.063/14; where 14 is the total number of D/L subscribed by each BN--3x4 + 1x2).

Finally, the "unit" for Hierarchical Review is one reviewed message. For the case described, 26 messages per hour are currently changed during review. If the review procedure were altered such that only 25 messages were changed, the decrease in utilization is estimated to be 0.001 (0.013/26, actually 0.0005, rounded off to 0.001 in exhibit 3-9).

By the use of these figures the SYSCON can determine which management procedure or procedures he can implement to achieve the desired decrease in utilization. For example, he can decrease the operating level of each of the four battalion users by one level and achieve a total decrease in utilization of 0.16 (a reduction of 25 messages at an estimated value of 0.004 each). The SYSCON can also selectively place the third maneuver BN and the support BN at level C and remove the first and second maneuver BN from one D/L and achieve a similar decrease in the utilization. Observe also that the required 0.159 reduction in utilization cannot be achieved without reducing the operating level of one or more of the battalion subscribers. Eliminating all IMR requests (0.037), abandoning all hierarchical review (0.013), and removing all battalions as D/L members (0.063) could achieve only a reduction of 0.113, still short of the required 0.159.

The selection of an appropriate alternative requires that the SYSCON have knowledge of the value to each BN of each type of information received and also the value to other TOS users in the division of the information provided by these BNs. If, for example, the SYSCON knows that the first and second maneuver BN are in active contact with the enemy, then they are likely providing reports which are of value to BDE and division commanders and a reduction in their access to send information is not appropriate. Also, if it is known that the responses received via the SRI are of high value to the BNs, then a reduction of those SRI as a means to achieve the non-overloaded state would not be acceptable.

With his assessment of the battlefield situation, the SYSCON must decide how to change the overload state of the communications net. For the purpose of example, suppose that the SYSCON perceives that the third maneuver and support BN can be placed at operating level C, achieving a reduction of 0.160 in the utilization of the net. In addition, all the hierarchical review could be eliminated, since the message now being sent from these two units should be equivalent to the most complete and accurate of the previous set, and the messages sent from the first and second MAN BNs are generally of high quality. This would decrease the utilization of the net further and possibly increase the rate at which the net returns to a satisfactory state.

The procedure for choosing the appropriate management action is clearly not methodical and obviously complicated. The SYSCON will likely find such management difficult, but rather than taking a "shot in the dark," the statistics which should be made available to him allow him to have confidence in his management action that the overload will be corrected. The more the SYSCON knows about the battlefield situation and each user's role in the mission, the more likely the choice of which management procedure to employ will be simpler and acceptable to the affected users. If the SYSCON's knowledge does not allow him to make effective management decisions, then each user may need to be involved in the process and the SYSCON would be responsible for coordinating the effort to ensure that the necessary reduction in utilization is achieved.

3.3.2 COMPUTER PROCESSORS

The computer processors are the hardware devices which act on jobs (the basic information-handling activities visible to a user, e.g., updating a file) as they are routed through the Division Computing Center (DCC), e.g., the front end processor or the message disk controller. Analysis of the computer processor components has shown that the message disk controller and the data disk controller are the only processors which have potential overload problems. Therefore, any further reference to computer processors refers to these controllers specifically.

An overload of the computer processors may occur because of a hardware or software failure or because of excessive demands placed on the system. Computer system diagnostics and maintenance procedures and fault detection and isolation functions are available to identify and correct hardware and software problems, but management procedures are necessary to deal with the information needs of TOS users between the time of failure and correction. Also, if the failure is planned, for example, a system shut-down for displacement, management procedures are necessary to allow users to prepare for the shut-down and to deal with the outage. In all cases, though, upon restoration of the lost capability, TOS users can be expected to make inordinate demands on the system, both to provide and to obtain information. Management procedures are necessary to deal with this situation because these peaks in demands on the system may be so great as to cause substantial delays in processing and possibly a system crash. Also, TOS users could possibly overload the system during normal operations by placing excessive demands on the system. "Covering all bases" by extensive querying or submitting broad range or large numbers of SRI can be disastrous as was experienced in FM-222. If old information (data records) and outdated information retrieval requests are not purged from the system, a system overload may occur simply because the size of the data base which must be searched and the number of jobs that must be served are beyond the processor's capacity. Management procedures to deal with these problems must limit the number, and possibly the type, of information retrieval requests a user makes, prioritize the input of new information in times of high system use, and motivate users to purge old information and data requests.

The management procedures which are most likely to be effective in dealing with problems of overloaded computer processors are those that limit the number of jobs the processor must perform. These are procedures I and II which limit the number of information retrieval requests and the number of inputs and queries (operating levels), respectively.[25] Once an overload of a computer processor is identified, the SYSCON would have to analyze the potential of each of these management procedures to reduce the utilization of the disk controller. Then by judging the impact of each procedure on the quality of information processed by the system, he would decide how this would be accomplished. If, for example, it were decided that reducing the number of thresholds and correlations would be effective, determining which ones to delete would be dependent on the value to the users of the information retrieved by these requests. In the following example, consider that an overload of the data disk controller has been identified and that the SYSCON will need to decide quickly on the appropriate management action. Again, as in the case of an overload of a communications net, the SYSCON is assumed to have knowledge of the types of messages by function and by origination which compose the load on the processors, the value of each user's access to TOS to the success of the mission, and the importance of each type of message to the users.

AN EXAMPLE: OVERLOAD OF THE DATA DISK CONTROLLER[26]

The jobs performed by the data disk controller are to read and write messages and other data from the data disk. Any incoming message, except relays, will task the data disk controller either to add a new message to the data base, or to search keys and key values for particular types of messages. For this example assume that the SYSCON has determined that the utilization of the data disk controller should be kept at or below 0.600 for safe and satisfactory system operation.[27] The monitor statistics available to the SYSCON, given in exhibits 3-10 and 3-11, indicate that the utilization of the data disk controller is above this value and it is necessary that he invoke management controls. From these, the SYSCON can estimate the potential for

[25]The configuration of the software design analyzed in the study assumed that the message disk controller would write a copy of a response message to the message disk for each user to whom it is to be sent. In this case, the removal of a user from a distribution list may also be an effective management procedure.

[26]The jobs performed by the data disk controller and the procedure by which they are accomplished is dependent on the hardware and software design. Since these were not firm at the time TOS project work halted, a design was assumed based on available documentation so that overloads which might occur and the impact of management procedures to correct these problems could be examined.

[27]The factors affecting the value of utilization at which a TOS component should be identified as overloaded are discussed in detail in chapter 4.0.

EXHIBIT 3-10: EXAMPLE LOADINGS ON THE DATA DISK CONTROLLER

USER	IMR REQUESTS ORIGINATED				UPDATES	QUERIES	OPERATING LEVEL*			
	SRI	THRESH	CORR	FILTER			A	B	C	D
TOTAL	100	50	50	25	1095	260				
INTEL	17	15	18	15	115	28	**	200/50	100/25	0/0
OPS	15	15	18	10	9	7	**	50/25	25/10	0/0
TAC CP	9	9	14	--	100	25	**	200/50	100/25	0/0
DIVARTY	3	3	--	--	73	3	100/20	80/10	40/5	0/0
ENG	4	--	--	--	58	5	100/20	80/10	40/5	0/0
ADA	3	--	--	--	20	3	50/20	25/10	10/5	0/0
CAV-SQN	11	8	--	--	148	9	200/20	150/10	50/5	0/0
AVN	3	--	--	--	48	9	100/20	50/10	50/5	0/0
DISCOM	1	--	--	--	5	5	50/25	25/10	10/5	0/0
CEWI	3	--	--	--	98	25	200/50	150/25	50/5	0/0
TACFIRE	0	--	--	--	8	25	25/50	10/25	0/5	0/0
ADJDOV	0	--	--	--	15	25	25/50	15/25	0/5	0/0
NATO	0	--	--	--	15	25	50/50	25/25	0/5	0/0
SYSCON	0	--	--	--	8	0	**	**	**	**

*Circle Indicates Current Operating Level **No Bound on Use

EXHIBIT 3-10: EXAMPLE LOADINGS ON THE DATA DISK CONTROLLER (Continued)

USER	IMR REQUESTS ORIGINATED				UPDATES	QUERIES	OPERATING LEVEL*			
	SRI	THRESH	CORR	FILTER			A	B	C	D
BDE1	5				8	12	40/30	30/20	20/10	0/0
MAN BN1	2				32	7	40/10	30/5	12/3	0/0
MAN BN2	2				32	7	40/10	30/5	12/3	0/0
MAN BN3	2				32	7	35/10	30/5	12/3	0/0
CS BN	0				25	0	30/10	25/5	9/1	0/0
BDE2	5				15	12	40/30	30/20	20/10	0/0
MAN BN1	2				12	7	40/10	30/5	12/3	0/0
MAN BN2	2				10	7	40/10	30/5	12/3	0/0
MAN BN3	2				10	7	35/10	30/5	12/3	0/0
CS BN	0				10	0	30/10	25/5	9/1	0/0
BDE3	4				15	12	40/30	30/20	20/10	0/0
MAN BN1	2				5	3	40/10	30/5	12/3	0/0
MAN BN2	2				5	3	40/10	30/5	12/3	0/0
MAN BN3	2				5	3	35/10	30/5	12/3	0/0
CS BN	0				7	0	30/10	25/5	9/1	0/0

*Circle Indicates Current Operating Level **No Bound on Use

EXHIBIT 3-11: CALCULATED UTILIZATIONS OF DATA DISK CONTROLLER[1]

PROCESSING FUNCTION	UTILIZATION
SRI	0.1970
Threshold	0.1108
Correlation	0.0910
Filter	0.1210
Update	0.1083
Query	0.0723
TOTAL	0.7003
(Threshold for Overload)	(0.6000)

[1]From the example loadings given in exhibit 3-10.

each of the management procedures to decrease the utilization of this controller as shown in exhibit 3-12.[28] In parentheses are the gradiants of these decreases. For example, if one SRI is eliminated the expected decrease in utilization of the data disk controller is 0.0020.

In the case of operating levels, if they are changed such that one less update message is eliminated, the expected decrease in utilization is 0.006. From the information in exhibit 3-12 it is apparent that a reduction in operating level holds the most potential for a decrease in utilization as no processing is performed by the data disk controller if no demands are made. This level of decrease is likely unnecessary and not satisfactory to any user, although from the monitor statistics available to the SYSCON and shown in exhibit 3-10, the SYSCON could selectively place users at lower operating levels such that the necessary decrease in utilization is achieved. For example, decreasing the operating level of the ENG BN and CAV SQN to level C and the operating level of the three man BNs of BDE1 to level B the decrease in operating level would be 0.0762.[29] The management procedure which produces the greatest effect per unit decrease in access is elimination of filter requests. Yet there are so few filters, it is likely that the necessary decrease in utilization can not be obtained by eliminating filters only and still maintain user satisfaction with the decreased access.

Now, based on his knowledge of the user's information needs, the SYSCON would have to decide the appropriate management procedure to employ. Assume that in the SYSCON's judgment the access permitted by the current operating level of each user is at or below the level at which the information requirements of the division are met; therefore, changing operating levels would not be considered appropriate management action. This leaves the reduction of the number of incoming message retrieval requests as the only alternative action. Without extensive information as to the specific characteristics of

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[28] The calculations necessary to make these estimates are lengthy and cumbersome, yet they are necessary for ensuring that the management action which is taken is effective in returning the component to a non-overloaded state. The equations utilizing the monitored statistics given in exhibit 3-10 are given in the appendix. It is believed that the SYSCON will need a decision aid (computerized or a series of tables) in order to make these estimates in a short time.

[29] The calculations necessary to make this estimate are as follows:

Decrease in updates:	ENG BN:	58 - 40 =	18
Current load -	CAV-SQN:	148 - 50 =	98
New Operating level load:	MAN BNs:	(32-30)x3 =	6
	TOTAL:		122
Decrease in queries:	ENG BN:	5 - 5 =	0
Current load -	CAV SQN:	9 - 5 =	4
New operating level	MAN BNs:	(7-5)x3 =	6
	TOTAL:		10
Decrease in utilization:	(122x0.0006) + (10x0.0003) = 0.0762		
	(Decrease in load x gradient)		

EXHIBIT 3-12: QUANTITATIVE EFFECT OF MANAGEMENT PROCEDURES ON DATA DISK CONTROLLER CALCULATED FROM EXAMPLE LOADINGS

MANAGEMENT PROCEDURE	DECREASE IN UTILIZATION (Gradiant of Decrease in Utilization)
1. Reduce IMR Requests	0.5198
SRI	0.1970 (0.0020)
Threshold	0.1108 (0.0022)
Correlation	0.0910 (0.0018)
Filter	0.1210 (0.0048)
2. Change Operating Level	0.0
Updates	------[1] (0.0006)
Queries	------[1] (0.0003)
3. Purge	Not Applicable
4. Remove User from D/L	Not Applicable
5. Alter Hierarchical Review	Not Applicable

[1] The operating level control procedure does not permit the reduction of updates and queries separately; therefore, it is not reasonable to estimate the potential of each of these to reduce the utilization of the data disk controller.

each of these requests, it is difficult to determine which ones are burdening the system; for example, by being triggered often or invoking a query which has many key values specified and consequently requires many searches of the inverted key buffer, etc.[30] One option for the SYSCON is to set a time frame or specific user as a qualifier on the commands to eliminate specific requests. In the event that a valuable request is eliminated, the originator (who is automatically notified of deletion) might then delete a less valuable request and replace it with the one selected for elimination by the SYSCON. To obtain any information he may have missed, the user may also choose to query the data base.[31] Since the utilization of the data disk controller needs to be decreased by 0.1003 (exhibit 3-10), an across-the-board 20 percent decrease in incoming message retrieval requests--20 SRI, 10 THRESH, 10 CORR, and 5 FILTERS--would achieve the desired effect (0.5198 x 0.20). Alternatively eliminating 11 FILTERS and 25 SRI is also sufficient to return the processor to a non-overloaded state [(25 x 0.0020) + (11 x 0.0048)]. As stated in subsection 3.2.1, the decision depends on the value to the users of the information received by these functions and the effects on the quality and quantity of messages stored in the data base by eliminating correlations, thresholds, and filters.

3.3.3 COMPUTER STORAGE OVERLOAD

A storage overload is characterized by the saturation of any of the memory buffers, e.g., the disks or core memories. The saturation may occur because of an overgrown data base, a communications net failure (the messages to be transmitted on the net are stored in buffers), or a user overload (the messages which are sent to a user are stored in core at his terminal until he has the time to review them). A storage overload at the DCC, in all probability, will keep the DCC from processing information in a timely manner and users will experience long delays in the receipt of information. Also, depending on the design of the system software, the saturation of particular buffers may result in a lockout of the receipt or transmittal of information

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[30]In this case, it is obvious that the users may be in better position to implement the management procedure than the SYSCON. For example, if it were determined that elimination of 10 percent of the incoming message retrieval requests would produce the required results, then each user could be directed to do so, likely resulting in increased satisfaction of the users as they are able to choose which requests are eliminated.

[31]Since it is difficult to determine the decrease in utilization achieved by eliminating these requests as the probability they are triggered, the search criteria, etc., may be very different from request to request, it may be necessary that more requests than are determined necessary are deleted to increase the likelihood that a non-overloaded state is actually obtained. The impact of this decrease in access on other forms of utilization of the system (e.g., more querying or replacing requests not useful with those eliminated) is also difficult to assess and another reason the number of requests eliminated might need to be more than the number determined necessary.

or perhaps the destruction of part of the operating system. Due to the catastrophic nature of this problem, management procedures are necessary to prevent the possibility of the saturation of any of the buffers.

One management procedure to prevent the occurrence of an overload is to monitor the rate of incoming messages, to estimate the expected time until saturation of the buffers, and then to decrease the arrival rate as necessary. Another management procedure is to purge the data base to prevent the disk from becoming saturated. This procedure must include preventative as well as "as required" methods for purging, as the time and processing necessary for purging place a burden on the users and the system. In response to an identified buffer overload if the condition is due to the overload of another component, a decrease in the utilization of the other component will decrease the utilization of the associated buffer.

An attempt to store too many data records in the disk files exemplifies the case in which a storage overload is not the result of another overload. In this situation, management procedures which decrease the amount of information stored are effective. An increase in the number of correlations and thresholds, and a decrease in the rate of incoming messages (changes in operating level) are likely to be effective but also are likely to be slow in correcting the problem. The most effective management procedure is purging, particularly "as required" purging. The SYSCON should continually monitor the utilization of the data base disk storage and advise the file managers when they are overloaded. The SYSCON would also need to advise the file manager of the amount of reduction necessary in order to return the file to the desired size. The file manager would then be responsible for constructing the purge queries to meet both the battlefield situation and the TOS system requirements. The file manager must also choose between deleting the records without review or reviewing each record to decide if it should be deleted. Such decision would likely be based on the time which is available to conduct the purge and the types of records which are to be deleted.

3.3.4 USER OVERLOAD

A user is considered overloaded if: (1) he is required to compose and transmit more messages in a period of time than he is physically or mentally able; (2) he receives more information than he is able to assimilate in a period of time; (3) he receives unreasonable amounts of outdated or useless information which he must separate from the timely and useful information; or (4) any combination of the three tasks above beyond his capabilities. A user overload is not as readily identifiable as other components as it is not easy to define a user's capacity. Guidelines could be set up which might indicate a possible overload; for example, if the weighted sum of the number of input and output messages is beyond some threshold, then the user is assumed to be overloaded. Certainly, every individual has a different capacity to process information and what is an overload for one person might well be a comfortable load for another. A user overload is very dependent on each user's individual capabilities as well as his functions in addition to interacting with TOS, and very difficult for the SYSCON to manage effectively. The user can and will likely handle the situation himself if he feels overtasked, as he can request to be removed from D/L or eliminate some of the

incoming message retrieval requests to reduce the amount of output he receives. Further, he can reduce the number of query messages and updates submitted. The problem of a user overload is best addressed then by providing the user with: (1) advice of information constraints (message types and subjects not currently wanted by the commander and his staff) and information needs (message types and subjects in demand); (2) guidelines for message preparation--particularly the definition of data entries for which there is no DED entry, free text fields and descriptions; and (3) default distribution lists defining to whom to send the information if the originator is unsure of who may be interested.

The TOS user is the most critical component of the TOS system and success of the system ultimately lies in his satisfaction. It is therefore necessary that he understand what TOS can do for him and how he is to use the system to perform these tasks. All information management procedures should work together such that the TOS user can most effectively use the capabilities without feeling restricted or unnecessarily burdened.

4.0 PROCEDURES FOR DETECTING A TOS SYSTEM OVERLOAD

An entire procedure for managing a TOS system overload can be depicted as in exhibit 4-1. Chapter 3.0 discussed steps 2-4, specifically the alternative actions (management procedures) available to the SYSCON and methods to analyze the overload in order to decide on the appropriate management action. This chapter addresses the procedure for detecting an overload including the considerations which are necessary before an exact definition of a component overload can be recommended. In the event an overload cannot be identified by automated means, an example of a process for detecting an overload is also developed.[32] In section 4.1 the factors which impact the definition of an overload are discussed. Then, in section 4.2, a definition of an overload and procedures for identifying the overload are developed using the CAV SQN FM communications net as an example because an operational definition of an overload and procedures for identifying an overload are dependent on the component itself. In the final section of this chapter, the monitoring of the system described in chapter 3.0 and in the first sections of this chapter are summarized to indicate the range of parameters characterizing the TOS system which need to be available to the SYSCON in order to control the system effectively.

4.1 THE CONSIDERATIONS FOR DEFINING A COMPONENT OVERLOAD

The term overload is used in chapter 3.0 to identify when the SYSCON needs to take management action to ensure that the TOS system remains responsive to user needs and that a system crash is avoided. This overload refers to a state of the component where its utilization is above some desired threshold. The determination of the appropriate threshold value is complex and needs to consider three basic factors: (1) the responsiveness that is required of the system; (2) the means by which the utilization of the component is measured; and (3) the procedures which are available to circumvent the problem.

The responsiveness that is required of the system includes the utilization which can be tolerated by the hardware and software without causing a system crash and the utilization which can be tolerated by the users interfacing the system. A definition of overload suggested by the concept of operational capacity presented in chapter 2.0 considered primarily these requirements. Operational capacity is defined as the demand which produces a utilization of 80 percent. The analysis indicating this value showed that at utilization of greater than 80 percent the expected waiting time and expected queue length quickly exceed the system requirements given in the A- and B-level specifications. Further, it acknowledges that at utilizations of less than 80 percent, control of demand is a nearly linear control for expected delay. This analysis suggests that an upper bound on the threshold is 0.8 utilization.

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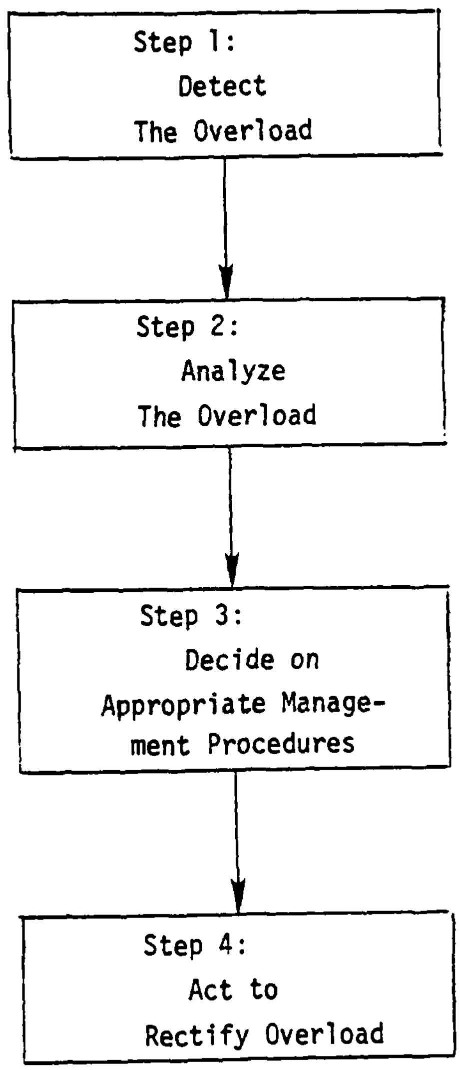
[32]The design of the hardware and software for the computer system will determine the extent to which the detection of an overload is automatic.

EXHIBIT 4-1: PROCEDURE FOR MANAGING A TOS SYSTEM OVERLOAD



Factors which might necessitate that this threshold be lower are the means by which the utilization of the component is measured. If the utilization is computed automatically by computerized monitoring of busy and non-busy periods, then the primary concern is the period of time over which the utilization is measured or the integration period. If the period is too short, sporadic increases in system use might be observed and the net will be incorrectly identified as congested, whereas, if the integration period is too long, the net may have become overloaded but measurement of the overload is masked by the adjacent periods where the utilization was low. Given the integration period, the utilization threshold value can be set, such that the occurrence of these errors is minimized. If the utilization must be measured by some other more manual means, concerns such as the degree to which accurate data on the use of the system can be obtained, and the amount of manual effort required to calculate the utilization become important when determining the appropriate value of the threshold. In chapter 3.0 the utilization of the computer processor is measured as the number of times a processor must perform different tasks in a given time interval multiplied by the length of time it takes to perform each task divided by the time interval. The utilization of the communications link is measured as the number of messages that travel over that link in a given period of time times the length in characters of those messages divided by the number of characters that link can transmit in a given period of time. If the burden this monitoring places on the SYSCON is too great, the threshold value might need to be set much lower than the requirement set by considerations of responsiveness only so that the SYSCON does not need to be constantly concerned as to whether a system crash is imminent.

The third factor influencing the appropriate value of the threshold is the quantitative relationship between the cause of the problem and the procedure for correcting the problem. For example, if a disk processor is being tasked to perform more jobs than it can handle, an appropriate management procedure might be to reduce the number of jobs arriving at the processor. The time it takes to complete each job, the number of jobs "backlogged," the time it takes to implement the management procedure and the new rate at which jobs are arriving all impact the time it takes for the processor to return to a state where jobs are being processed in a timely manner. In determining the appropriate value of the threshold, these kinds of factors must be considered so that a system disaster is not incurred between the time the overload is detected and the time the effects of the management action are seen.

These three factors are basic for determining the value of the threshold for identifying the overloaded state of any component but the actual value which is appropriate for a specific component depends on the operating characteristics of the component itself. As an illustration, in the next section the CAV SQN FM net is considered. The factors specific to determining the appropriate threshold value for this component are discussed. Also included is an example of how the SYSCON could determine the utilization of the component in the absence of automated detection. Given are the monitor statistics which need to be available and the calculations which need to be made in order to estimate the utilization of the net.

4.2 AN ILLUSTRATION: DETERMINATION OF AN OVERLOAD OF THE CAV SQN FM NETS

The analysis of the TOS system has shown that the FM communications nets are likely to cause long delays in the transmission of messages. Those long delays are due to a demand by TOS users to transmit information over these nets in excess of the net capacity. To prevent these delays the use of the FM nets can be monitored such that when delays are likely to become unacceptable, control procedures are implemented to prevent this from occurring. The first task, therefore, is to determine when the net is being overutilized or overloaded and, secondly, to determine which control procedure to implement to alleviate the situation. Chapter 3.0, particularly subsection 3.3.2, discusses the second of these two tasks and the previous section presents basic considerations affecting the appropriate definition of an overload. In the following paragraphs, two other considerations unique to the communications nets are discussed; then an example of how the SYSCON would detect an overload is presented. The two additional factors unique to an overload of communications nets are related to the user requirements factor given in section 4.1: (1) the user interface and (2) the battlefield situation. The CAV SQN FM net is used as the example component for describing how an overload could be detected manually if it cannot be detected by automated means.

The first factor, user interface, considers the demands placed on the user at different levels of utilization of the net. For example, without any automatic transmission of the messages, if the net is utilized 80 percent of time, a user would experience a "busy signal" 80 percent of the time he tried to access the net. However, in TOS, the transmitter will automatically try three successive times to access the net. If the net is not obtained, the transmission attempt is terminated and the user is notified.[33] No further automatic processing occurs until the operator's instructions are received. The long delays associated with human decisionmaking and response make it imperative that the human role in data transmission be minimized. Further, the burden placed on the operator by these requests for instructions may lead to rejection and hence failure of the system. Exhibit 4-2 depicts the probability that the operator is told the line is busy as a function of the time between automatic retries to obtain the line.[34] At best, at 80 percent utilization the user will be told that the line is busy approximately 50 percent of the time. If this is unacceptable with respect to human factor considerations, then the utilization threshold may need to be set lower than 80 percent.

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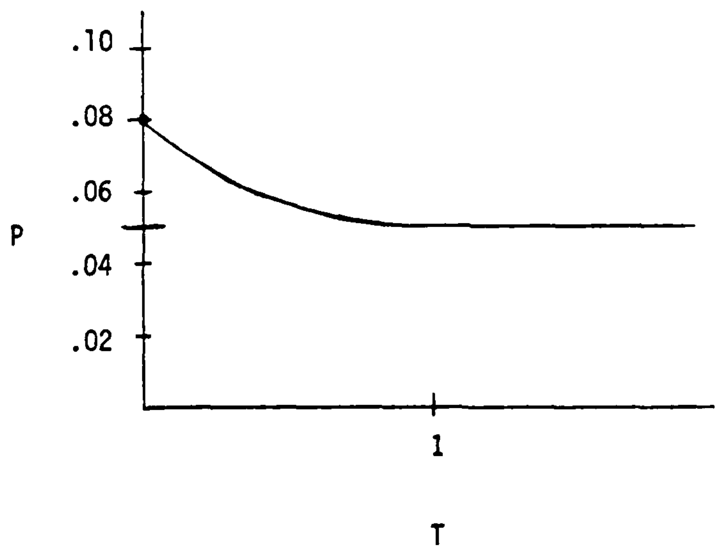
[33]In addition, the user is notified if the line is obtained but errors in transmission caused the message to be received incorrectly three times. See Volume III: Analysis of the Tactical Operations System.

[34]The time between automatic retries to access the net by the transmitter is important to the success of the transmitter to access the net as seen by the graph, but this is fixed by the hardware and software design and not subject to management action.

EXHIBIT 4-2: EFFECT OF 0.8 UTILIZATION OF A COMMUNICATIONS NET ON THE USER TRYING TO OBTAIN THE NET

$$Pr \approx (.8)^3 + \left[(.8) - (.8)^3\right] e^{-4T}$$



Where P is the probability that the user is told the line is busy when operating at time constant T and utilization = .8; and T is the time in minutes between automatic retries by the communications hardware to obtain the net.

The second factor, battlefield situation, refers to conditions which occur on the battlefield when a commander needs to have complete or a very high probability of access to the communications net, or where a short response time to queries or incoming message retrieval requests is demanded by a commander. These changes in requirements for access would be considered temporary and in response to particular battlefield conditions. For such situations the utilization threshold may need to be decreased to insure that the access which is needed is realized by the commander.

With the conditions determined for when a net is identified as overloaded, the SYSCON can use this guideline to determine when the employment of management controls are necessary. The SYSCON is responsible for monitoring the FM nets and determining the state of overload. The simplest way would be to have automatic monitoring of the net to determine the utilization, and once the threshold is exceeded, the SYSCON would be notified, either by a warning message or signal. Barring any sort of automation the SYSCON is still able to estimate the utilization of the communications net. The data which needs to be available to the SYSCON are given in exhibit 4-3 and are obtained by counting both the total number of times the user attempted to get a line and the number of times the user attempted but found it busy for the integration period. These figures are obtained at the transmitter of each transmitter-receiver pair. For the case of the CAV SQN FM net, only two pairs utilize the net, one at the DCC and one at the CAV SQN, whereas the BDE-BN FM net would have 8 pairs--1 pair each BN (with the transmitter at BN) and 4 effective pairs at the BDE level (with the receivers at BN). Then the SYSCON would need to make the calculations given in exhibit 4-4. This procedure simply estimates the utilization by sampling the line (every time a user wants to transmit a message) and calculating the fraction of time it was found busy. If the utilization is above the threshold value for identifying a component as overloaded, the SYSCON would then need to obtain the data describing the cause of the overload and take the appropriate management action as described in chapter 3.0.

4.3 MONITOR STATISTICS FOR MANAGING TOS

The monitor statistics described in chapter 3.0 and in the previous section of this chapter can be characterized into two basic types: those which are monitored to detect a component overload and those which are monitored in order to understand how to rectify the overload problem. Within this second type there are three kinds of statistics: those which describe how each type of demand (update, query, etc.) affects each type of component, those which describe the current load (demand) on each component, and those which measure the impact of the load on each component. It is necessary for the SYSCON to have available to him statistics of each kind in order to control the system effectively. In addition, as discussed in chapter 3.0, he also needs to have knowledge of the information needs of each user of TOS within the division and the methods by which these users obtain their information needs (e.g., queries vs. SRI) for ensuring that the users remain satisfied with the management control.

EXHIBIT 4-3: EXAMPLE MONITOR STATISTICS TO DETECT AN OVERLOAD OF BDE-BN FM NET

Frequency that

BDE attempted to TRANSMIT

BDE got a BUSY signal

MAN BN 1 attempted to TRANSMIT

MAN BN 1 got a BUSY signal

MAN BN 2 attempted to TRANSMIT

MAN BN 2 got a BUSY signal

MAN BN 3 attempted to TRANSMIT

MAN BN 3 got a BUSY signal

DS BN attempted to TRANSMIT

DS BN got a BUSY signal

EXHIBIT 4-4: CALCULATION TO ESTIMATE UTILIZATION OF BDE-BN FM NET

$$\text{UTILIZATION} \approx \frac{\text{Sum of Frequency of BUSY Signals}}{\text{Sum of Attempts to TRANSMIT}}$$

The monitor statistics which are needed to detect an overload of the system are dependent on the degree to which the hardware and the software of the system automatically monitor the status (utilization) of each component. In the example provided in section 4.2 the data which are collected are used to estimate the utilization of a brigade FM net in the absence of any automatic monitoring. For other components it would be necessary to develop similar surrogate methods for monitoring their utilization if provisions for monitoring are not included in the hardware and software designs.

Once overload is detected, data such as are described in chapter 3.0 need to be used to determine the management action appropriate for rectifying the overload. The example loadings given in exhibits 3-7 and 3-10 describe the demands placed on the system; in particular, those related to the brigade communications net and the data disk controller respectively. In addition to monitoring the loadings, the SYSCON needs to have available the operating level guidelines defined for each user and the D/L on which each user is a member in order to manage the system effectively. These monitoring statistics are listed again for reference in exhibit 4-5. Other statistics which need to be monitored are those which describe how the demands (SRI, queries, etc.) impact the system. These statistics are exemplified in exhibit 3-3 for the IMR requests, but it is also necessary that similar data be available for queries and updates. When quantified, these statistics describe the expected or average value for all of the requests of a particular type. For example, the frequency with which the IMR criteria of the SRI requests are satisfied characterizes all the SRI requests and not each one individually. Therefore, when these statistics are used to calculate the quantitative effect of a management procedure, the result is an estimate of the change in utilization which may be realized by implementing these procedures. Exhibit 4-6 lists the monitor statistics given in exhibit 3-3 augmented by those necessary for updates and queries. A combination of these statistics and the loadings allow the SYSCON to determine the utilization of the component due to the different types of demand and the effectiveness of each management procedure to resolve a system problem once identified. The SYSCON needs to be kept aware of the sources of the various demands which have accumulated and the extent to which they are causing a component to be unduly stressed so that he can choose the control procedures most appropriate for dealing with that situation.

As argued in chapter 1.0, and evidenced here by the number and variety of items which must be monitored in order for the SYSCON to control the system, provision for monitoring the status of the system components must be included in the hardware and software designs. Also clear is the relationship between the two major considerations governing the extent to which the monitoring capability should be designed. That is, if the magnitude of the management task becomes too large, so will the amount of information necessary to be monitored, and vice versa.

EXHIBIT 4-5: EXAMPLE MONITOR STATISTICS FOR DETERMINING THE LOADING ON TOS COMPONENTS

For Each User:

- IMR Requests Originated
  - SRI
  - THRESH
  - CORR
  - FILTER
- IMR Responses Received
  - SRI
  - THRESH
  - CORR
  - FILTER
- Updates Originated
- Updates Response - Total
- Update Responses - Received via D/L
- D/L a Member of
- Queries Originated
- Messages Altered or Deleted by Hierarchical Review
- Operating Level Guidelines

EXHIBIT 4-6: EXAMPLE MONITOR STATISTICS FOR DETERMINING THE IMPACT OF DEMANDS ON TOS COMPONENTS

Demands: Incoming Message Retrieval Requests

(SRI)

- Number of SRI on the system
- Frequency that IMR criteria for SRI are checked
- Frequency that IMR criteria for SRI are satisfied
- Distribution of SRI response
- Length of SRI responses

(THRESH)

- Number of Threshold queries on the system
- Frequency that IMR criteria for threshold queries are checked
- Frequency that IMR criteria for threshold queries are satisfied
- Frequency that threshold criteria are satisfied
- Distribution of threshold responses
- Length of threshold response
- Average number of keys and key values searched

(CORR)

- Number of correlations in the system
- Frequency that IMR criteria for correlations are checked
- Frequency that IMR criteria for correlations are satisfied
- Average number of queries triggered
- Distribution of correlation responses
- Length of correlation responses
- Average number of keys and key values searched

-- Continued --

EXHIBIT 4-6: EXAMPLE MONITOR STATISTICS FOR DETERMINING THE IMPACT OF DEMANDS ON TOS COMPONENTS (Concluded)

(FILTER)

- Number of filters in the system
- Frequency that IMR criteria for filters are checked
- Frequency that IMR criteria for filters are satisfied
- Frequency that a data base search is triggered
- Frequency that a filter response is required
- Distribution of filter responses
- Length of filter response
- Average number of keys and key values searched

Demand: Update Messages (Add, Change, Delete)

- Frequency that messages are originated
- Distribution of messages ty type (ESDA, ESDC, UTOD, etc.)
- Length of message
- Number of keys updated
- Distribution associated with messages

Demand: Queries

- Frequency that queries are originated
- Length of query
- Distribution of query response
- Length of query response
- Number of keys and key values searched

APPENDIX: EQUATIONS FOR DETERMINING UTILIZATION

Given in this appendix are the equations used in this analysis for determining the utilization of each of the TOS components discussed in this volume, specifically the communications nets, the message disk driver, and the data disk driver.

A.1 COMMUNICATION NET

$$UTIL_i = \frac{\sum_j \sum_k (NMSG_{ijk})\ (LMSG_k)\ (XMITS_k)}{CAP_i}$$

Where:

$UTIL_i$ = Utilization of communication net i.

$NMSG_{ijk}$ = Number of messages of type k sent over transmitter-receiver pair j utilizing the communication net i per hour.

$LMSG_k$ = Length of message type k, including header and trailer, in characters.

$XMITS_{ik}$ = Expected number of times message type k must be transmitted to be received correctly over communications net i.

CAP_i = The capacity of communications net i to transmit data in characters per hour.

and $XMITS_{ik} = 1/(1 - PERROR_i)BITSk + (BITS_k)(PERROR_i)(1 - PERROR_i)(BIT_k - 1.0)$

where:

$PERROR_i$ = Probability a bit will be in error for communications net i.

$BITS_k$ = Number of bits in message type k.

A.2 MESSAGE DISK CONTROLLER

$$UTIL = \frac{[2(SRIRSP + THRRSR + CORRSP + FILRSP + QRYRSP) + UPDRSP]}{CAP}$$

Where:

UTIL	=	Utilization of message disk controller
SRIRSP	=	Number of SRI responses generated per hour
THRRSP	=	Number of THRESHOLD responses generated per hour
CORRSP	=	Number of CORRELATION responses generated per hour
FILRSP	=	Number of FILTER responses generated per hour
QRYRSP	=	Number of Query responses generated per hour
UPDRSP	=	Number of update responses generated per hour
CAP	=	Service rate of message disk controller, number of message disk reads/writes which can be completed per hour.

A.3 DATA DISK CONTROLLER

$$
\begin{aligned}
\text{UTIL} = \Big\{ & \text{SRICHK} + \text{THRCHK} + (\text{THRTRG})(\text{THRKEY})(\text{VALKEY}) + \text{CORRCHK} \\
& + [(\text{CORTRG})(\text{CORQRY})]\ [(\text{CORKEY})(\text{VALKEY}) + \text{CORREC}] \\
& + \text{FILCHK} + (\text{FILTRG})(\text{FILKEY})(\text{VALKEY}) \\
& + \text{ADD}\ (1 + 2\ (\text{ADDKEY}))\ \text{CHG}\ (2 + 2\ (\text{CHGKEY})) \\
& + \text{DEL}\ (1 + 2\ (\text{CHGKEY})) \\
& + (\text{QRY})\ [(\text{QCYKEY})(\text{VALKEY}) + \text{QRYREC}] \Big\} \div \text{CAP}
\end{aligned}
$$

where

SRICHK = Frequency that the IMR criteria of the SRI are checked against incoming messages, number per hour.

THRCHK = Frequency that the IMR criteria of the THRESHOLD requests are checked against incoming messages, number per hour.

THRTRG = Frequency that the THRESHOLD query is triggered, number per hour.

THRKEY = Expected number of keys specified by THRESHOLD query.

VALKEY = Expected number of key values searched per key per data base search.

CORCHK = Frequency that the IMR criteria of the CORRELATION request are checked against incoming messages, number per hour.

CORTRG = Frequency that the CORRELATION is triggered, number per hour.

CORQRY	=	Average number of queries per CORRELATION request.
CORKEY	=	Expected number of keys specified by CORRELATION query.
CORREL	=	Expected number of records retrieved per CORRELATION query.
FILCHK	=	Frequency that the IMR criteria of the FILTER requests are checked against incoming messages, number per hour.
FILKEY	=	Expected number of keys specified by FILTER query.
ADD	=	Frequency that messages are added to the data base, number per hour.
ADDKEY	=	Expected number of keys to be updated by the addition to the data base.
CHG	=	Frequency that messages in the data base are changed, number per hour.
CHGKEY	=	Expected number of keys to be updated by the change to the data base.
DEL	=	Frequency that messages in the data base are deleted, number per hour.
DELKEY	=	Expected number of keys to be updated by the deletion of a record from the data base.
QRY	=	Frequency that the data base is queried (by QUERY requests), number per hour.
QRYKEY	=	Expected number of keys specified by the query.
QRYREC	=	Expected number of records retrieved per query.
CAP	=	Service rate of data disk controller, number of data disk reads/writes which can be completed per hour.

and VALKEY = LOG_2 (NKYVAL)

where:

NKYVAL = Expected number of key values per key.

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